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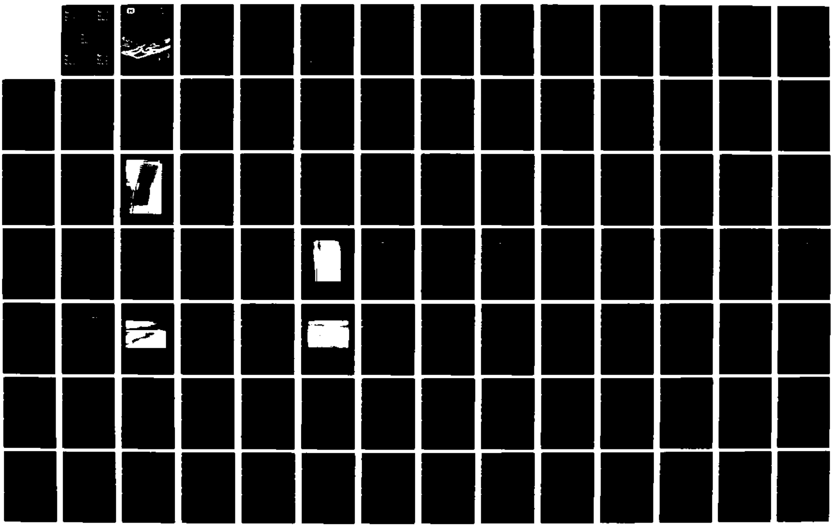

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WETLANDS RESEARCH PROGRAM

TECHNICAL REPORT Y-82-1

USE OF VEGETATION IN DELINEATING WETLAND BORDERS IN UPPER MISSOURI RIVER BASIN; NORTH-CENTRAL UNITED STATES

by

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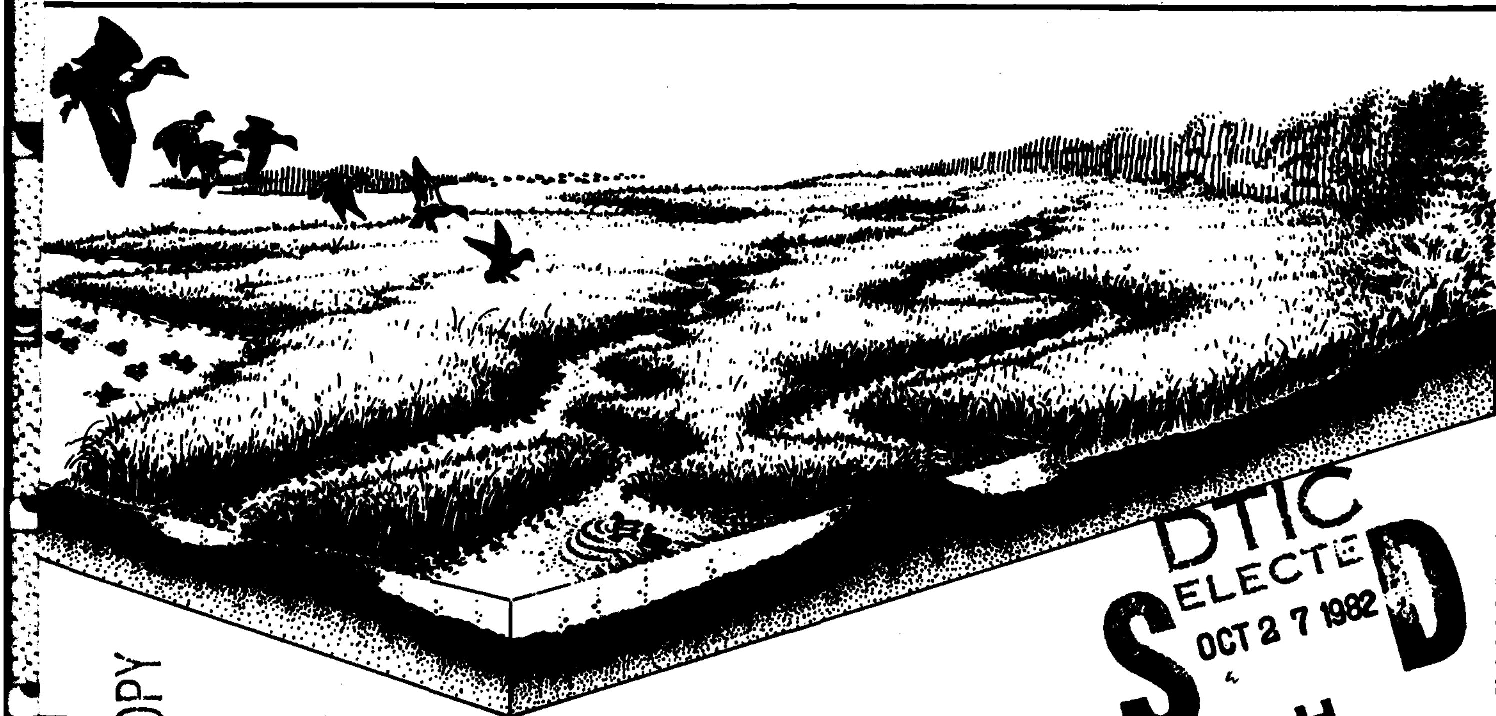
Final Report



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Wetland-nonwetland transition zones in the Missouri River Basin of the north-central United States were studied in seven wetlands ranging in size, permanence, and salinity to develop an efficient sampling methodology that utilized vegetation data to delineate wetland boundaries. One hundred and sixty species of vascular plants occurred in twenty sample transects. Sampling methodology suggested for use in the study area (200-km radius of

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20. ABSTRACT (Continued).

Sioux Falls, South Dakota) is a combination of the belt transect method (contiguous quadrats) to estimate cover by species and a cover board to measure vertical structure. The methods require a combined sampling time of about 9 min/m of transect, corresponding to a sampling time of 3.2 hr for a transect of average length. A streamlined methodology was also devised whereby sampling time could be cut in half.

General upper and lower borders of the transition zone were determined from direct gradient analysis graphs. Specific borders were determined from the occurrence of compositional dichotomies displayed in ordination models. The upper border of the transition zone is suggested as the most probable wetland border. This border appears to represent the upper limit of disturbance from wetland processes (siltation during drawdown, ice scouring, variable surface and subsurface hydrologic regime). The transition zone (between emergent aquatic and low prairie zones) is strongly influenced by wetland disturbances and, therefore, contains a large proportion of opportunistic, ruderal species. The lower border of the transition zone is highly variable annually, while the upper border appears to be relatively stable.

SUMMARY

The fundamental purpose of this research was to develop a sampling and analytical methodology using vegetation to delimit wetland-nonwetland borders and their transitions in the Missouri River Basin of the north-central United States (i.e., within a 200-km radius of Sioux Falls, South Dakota). The study area lies primarily within the eastern portion of the glaciated northern Great Plains and includes portions of South Dakota, Minnesota, Iowa, and Nebraska. The largest portion occurs in South Dakota; hence, the field research was conducted there. The potential vegetation of the region is mixed- and tall-grass prairie occasionally dissected by northern floodplain forest. Wetlands include a wide variety of meadows, marshes, small ponds, and lakes that support a complex of vegetation conditions. The region is highly agriculturalized; most remaining wetlands are either too large to be drained economically or are restricted primarily to landscapes with unproductive soils.

Little is known about transition zone vegetation in the study area proper, although considerable general research on wetlands has been conducted beyond the borders of the study area in North Dakota and Saskatchewan. In the northern Great Plains no research has been conducted that specifically deals in quantitative fashion with the delineation of wetland-nonwetland borders.

The research had three specific objectives: (a) to develop an efficient field sampling methodology which would enable the detailed examination of vegetation patterns along wetland-

nonwetland gradients, (b) to apply the methodology to ecologically diverse wetlands to streamline its use and evaluate its region-wide applicability, and (c) to utilize the field data and the appropriate analytical methods to quantitatively evaluate vegetation transitions and borders as they exist in study area wetlands. Three basic vegetation sampling methods were tested and evaluated: belt transect (contiguous quadrats), line-intercept, and cover board (vertical cover).

Seven wetlands ranging in size, permanence, and salinity were selected from within the study area. From these wetlands, a total of 20 transects was sampled along diverse wetland-nonwetland gradients. All transects were permanently marked. Conductivity and salinity were taken at each wetland, and slope measurements were taken along each transect. Cover by species was collected from contiguous quadrats using the belt transect design. Species frequency was determined using the line-intercept technique. Vertical structure (vegetation cover as a function of height) was estimated from a cover board that slides vertically on a metal pole. One hundred and sixty species occurred in the twenty transects.

The line-intercept method was the most time efficient, followed by the cover board, and finally by the belt transect. However, the line-intercept poorly estimated species' positions along the transect compared to the belt transect (quadrat) method. Structural data were found to be very useful in delineating the lower transition zone border (i.e., between emergent aquatic and transition zones). Thus, the methodology

suggested for use is a combination of the belt transect and vertical structure methods. The appropriate quadrat size for the belt transect is 0.5 by 0.5 m. Wider quadrats (e.g., 1 m) did not lead to significantly greater numbers of species sampled or improvement in the estimate of species' positions along the gradient. The sampling methodology (belt transect plus cover board) requires an average sampling time of about 9 min/m of transect. This corresponds to a sampling time of 3.2 hr for a transect of average length.

A streamlined method was also devised whereby sampling time could potentially be halved. Under conditions where the lower and upper portions of the transition zone are generally discernable from simple field observations, sampling could be confined to these two areas wherein lie the natural borders of the transition zone. The lower sampling area would typically include a portion of emergent aquatic and lower transition zones, while the upper sampling area would typically exhibit increasing cover of low-mid prairie species and decreasing cover of broad-leaved ruderal species and weedy grasses. The streamlined technique should be applicable to a large proportion of study area wetlands and would require only 1 to 2 hr of sampling time per average transect.

The basic analytical scheme was to broadly identify the lower and upper transitions from direct gradient analysis graphs which portray species cover along the wetland-nonwetland transects. Structural indices were also useful in identifying the lower transition. These transitions were each typically 2 to

5 m wide. Ordination was used to refine the gross position of the border to a specific 1- or 0.5-m segment of the transect. Ordination models graphically represented the compositional relationships among the samples within the lower and upper transitions. Significant dichotomies in composition, shown as breaks or gaps in the model, were the basis for tenatively establishing specific upper and lower borders. Ordination was less effective in delineating borders in highly disturbed communities such as tame pasture or overgrazed wetland margins.

The width of transition zones for representative wetlands ranged from near 0 to 14 m, with an average near 7 m. The upper border of the transition zone is the most probable wetland border for most wetlands studied. On the wetland side of this border occur a large number of ruderal species typical of moist, disturbed environments. Colonization of the transition zone by ruderals is undoubtedly facilitated by (a) the high plant mortality caused by a widely fluctuating hydrologic regime and (b) the erosion of existing vegetation during high water and subsequent deposition of silt during seasonal drawdown. Therefore, this border marks the upper limit of significant effects from the wetland. The upper border also appears to be relatively stable. For these reasons, the upper border of the transition zone should constitute the wetland border. The lower border of the transition zone is highly changeable annually and its position depends in large measure on early spring water levels.

In general, the methodology devised is time efficient and

accurate in representing species' positions along the moisture gradient. Ordination enables quantitative refinement of transition zone boundaries. The transition zone is strongly influenced by the wetland, especially inundation during high water levels, siltation during drawdown, and a widely fluctuating water table at or near the soil surface. These factors combine to enable colonization of the transition zone by ruderals. The wetland border and upper transition zone border are synonymous and represent the upper limit of disturbance from wetland processes.

Caution is suggested in accepting the borders delineated here as permanent borders because they are based on vegetation patterns as they existed during the 1979 growing season. Without knowledge of the temporal stability of the wetland border, it would be difficult to support, on scientific grounds, the 1979 border as a permanent border. Also, delineation of transition zone borders in areas heavily grazed or converted to tame pasture remains problematic. The study of underlying environment (e.g., soils and hydrology in conjunction with vegetation) is suggested as an auxiliary means for identifying stable wetland borders along disturbed wetland-upland gradients.

PREFACE

At the request of the Office, Chief of Engineers, the Environmental Laboratory (EL) of the U. S. Army Engineer Waterways Experiment Station (WES) conducted this research under the initial auspices of the Dredged Material Research Program (1978-1979) and later under the Dredging Operations Technical Support Program (DOTS). The objective of this effort was to develop guidelines and methodologies to aid Corps Regulatory personnel throughout the United States with the onsite identification and geographic delineation of wetlands that could be subject to regulation under the Section 404 of the Clean Water Act.

The purpose of this study was to assess several vegetation sampling methodologies and to determine which methodology best delineates the boundaries separating various wetland plant communities and their associated transition zones from nonwetland areas within the Interior-North Central United States. The research was performed under Contract No. DACW39-78-C-0098 (entitled, "Wetland Transition Zone Study Within the Upper Missouri River Basin of the North-Central United States") by the Virginia Polytechnic Institute and State University (VPI), Blacksburg, Virginia. Authors of the report were Drs. W. Carter Johnson (VPI), Richard A. Mayes (VPI), and Terry L. Sharik (VPI). Janet R. Johnson (VPI) and Peggy W. Reily (VPI) provided valuable assistance in the field. Computer analysis and graphics were performed by Thomas Finn (VPI). The report was typed by

Jackie Cumbee (VPI). Dr. Dilwyn Rogers provided access to the Augustana College herbarium in Sioux Falls.

Drs. Robert Terry Huffman and Gary E. Tucker, EL, developed the project's scope of work and provided technical assistance. Dr. Huffman also served as the Contracting Officer Representative for WES during the project. In addition, the research effort was under the general supervision of Dr. H. K. Smith, Environmental Resources Division (ERD), EL; Dr. C. J. Kirby, Chief, ERD, EL; Mr. Charles C. Calhoun, Program Manager, Dredging Operations Technical Support Program, EL; and Dr. John Harrison, Chief, EL.

The Commanders and Directors of WES during the study were COL G. H. Hilt, CE, COL J. L. Cannon, CE, and COL N. P. Conover, CE. Technical Director was Mr. F. R. Brown.

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PART I: INTRODUCTION

Background

1. The purpose of this research was to develop a sampling and analytical methodology to delimit wetland-nonwetland borders and their transitions in the Missouri River Basin of the north-central United States (i.e., within a 200-km radius of Sioux Falls, South Dakota). This research was conducted in response to Federal regulations mandated by Section 404 of Public Law 92-500 (Federal Water Pollution Control Act Amendments of 1972). In essence, the research was to develop a methodology that utilizes vegetation data to identify natural wetland-nonwetland borders, based on vegetation structure and composition.

2. The study area lies primarily within the eastern portion of the glaciated northern Great Plains and includes portions of four states (South Dakota, Minnesota, Iowa, and Nebraska). The largest portion occurs in South Dakota; hence, the studies were conducted there. The potential vegetation of the region is primarily mixed-grass prairie (*Agropyron*-*Andropogon*-*Stipa*) occasionally dissected by northern floodplain forests (*Populus*-*Salix*-*Ulmus*) (Kuchler 1964). The region is highly agriculturalized; remnant natural communities occur primarily on thin, stony soils too dry for agriculture or in lowlands that are

too wet during most years to successfully raise crops. Uplands surrounding wetlands are usually cultivated or grazed close to their margins unless the land is under public ownership (e.g., public shooting areas, Federal waterfowl production areas), in which case the uplands are sometimes protected from disturbance. Wetlands include a wide variety of meadows, marshes, small ponds, and lakes which support a complex of vegetation conditions. A major characteristic of wetlands in the glaciated prairie region is the extreme spatial and temporal variability in vegetation composition and structure.

3. Wetland vegetation within the study area is known only at the level of general classification (Evans and Black 1956; Stewart and Kantrud 1971). Little has been published that quantitatively describes vegetation zones and transitions. Stewart and Kantrud (1971) utilize zone juxtaposition to classify zones, but the nature of zone interfaces or the limits between uplands and lowlands or between wetlands, meadows, and low prairie remains undescribed. Moreover, no sampling or analytical techniques have either been developed in or have been applied to study area wetlands specifically aimed at delimiting zones and transitions.

4. The most extensive wetland research in the northern Great Plains has been conducted outside the study area in the prairies of southern Saskatchewan and central and northern North Dakota (Burgess and Disrud 1969; Dix and Smeins 1967; Millar 1973; Smeins 1967; Walker and Coupland 1968, 1970; Walker and

Wehrhahn 1971). Descriptive information relevant to the present study includes species lists, ecological tolerances of species to environmental conditions, classification systems, and numerous other general relationships between the wetland physical environment and vegetation cover. These studies, however, were primarily aimed at obtaining regional perspectives and, hence, do not attempt to identify borders for individual wetlands.

Objectives

5. Basic objectives of this research were to: (a) initially develop a field sampling methodology at one or several test wetlands that would enable the detailed examination of vegetation patterns along wetland-upland gradients, (b) apply the methodology to ecologically diverse wetlands to streamline its use and evaluate its region-wide applicability, and (c) utilize the field data and the appropriate analytical methods to quantitatively evaluate vegetation transitions and borders as they exist in study area wetlands.

Methodology

6. The sampling techniques developed should (a) accurately represent the dispersion of species along environmental gradients (i.e., their respective physical positions), (b) include the measurement of those vegetation parameters that are sensitive to environmental changes along gradients, (c) be time efficient,

yet realize that a significant number of sample transects would be needed to characterize wetland-upland transitions for a single wetland, (d) provide data compatible with advanced analytical techniques, and (e) be highly repeatable to allow for both the accurate remeasurement of permanently located transects and the use by other investigators and CE field crews.

7. The transect method was selected as the best sampling technique. Three basic variants to sample along the transect were tested and evaluated: belt transect, subdivided into contiguous rectangular subplots with the transect tape as the center line; line-intercept, represented by an imaginery vertical line above and below the transect tape; and vertical structure, measured by a cover board raised vertically on a metal pole.

Application

8. The field sampling techniques were evaluated in a diverse array of wetland sites. Initial methodology tests were conducted at Buffalo Slough (Figure 1). The methodology was later refined and streamlined at six other wetlands. Belt transect and vertical structure techniques were applied to all 20 transects; the line-intercept sampling technique was evaluated at transects 01-13. Seven transects were established at Buffalo Slough, two at Anderson Slough, three at Englehardt Slough, two at Platte Lake, and a total of five at three Ordway Prairie (Nature Conservancy) wetlands. Ecological conditions of the seven wetlands and twenty transects were sufficiently diverse (Appendix A) to constitute an adequate test of the applicability of the methodology to study area wetlands. All transects were

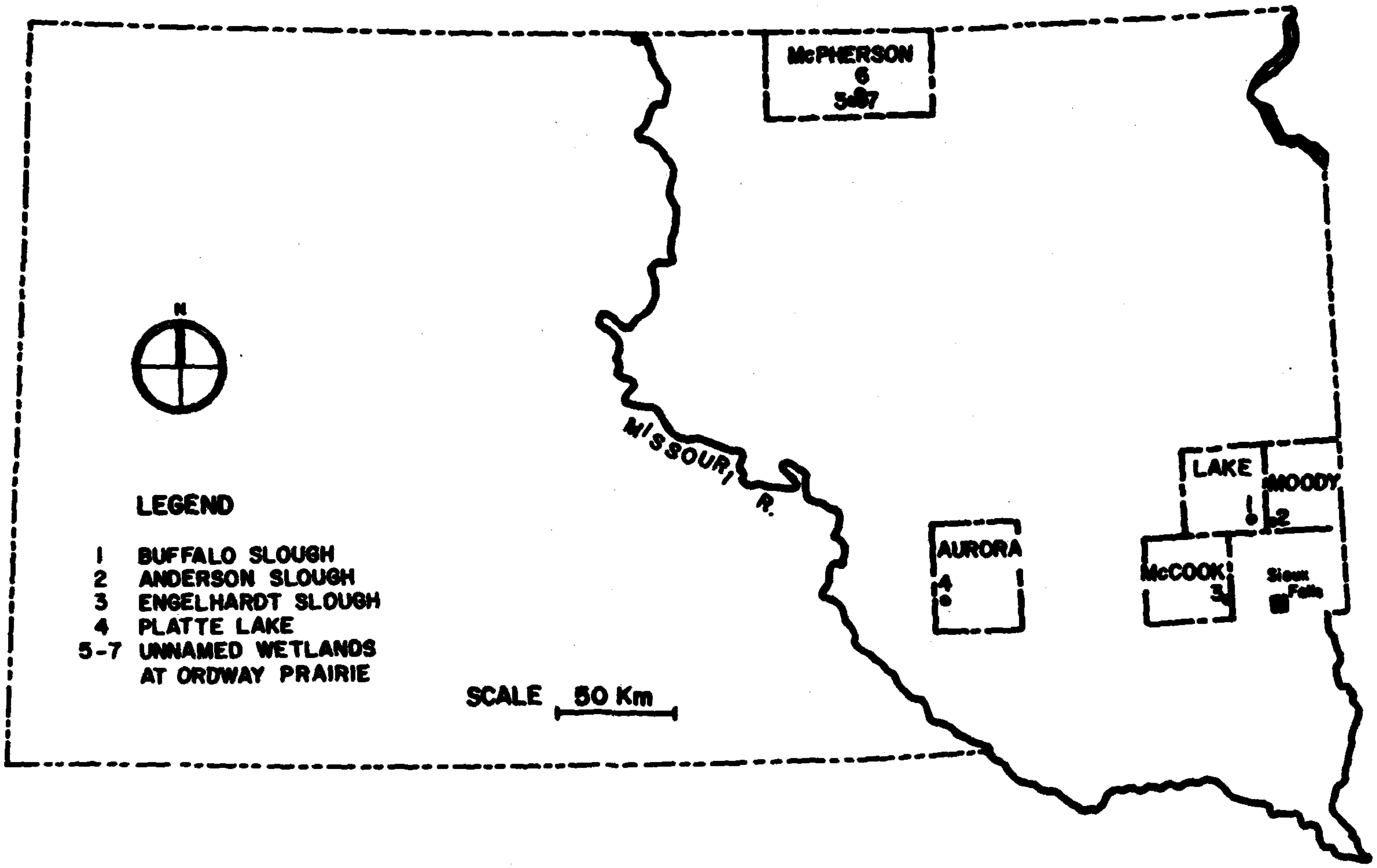

Figure 1. General location of study wetlands in eastern South Dakota. Specific locations and wetland characteristics are provided in Appendix A

permanently marked with a metal t-post at their lower end (meter 0) and a metal rebar at the upper end. Conductivity and salinity measurements were made in each wetland using a YSI Model 33 S-C-T meter. Slope percent was determined with a Suunto clinometer for each uniform slope segment. Botanical nomenclature follows Gleason (1952).

Data analysis

9. Data analysis was conducted at two levels. Direct gradient analysis models were constructed to graphically represent the relative positions of species and other vegetation variables (e.g., species diversity, vertical cover, presence) along the transect, using formulae from Johnson et al. (1976):

Species Diversity

$$H' = -\Sigma p_i \ln p_i$$

where p_i = probability of sampling the ith species

Evenness

$$E = 1.0 - R$$

where $R = (H'_{max} - H')/(H'_{max} - H'_{min})$

Variety = number of species that occur in a sample

The gross dichotomies that existed in vegetation were evident from this graphic analysis by inspecting the dispersion of population curves and changes in structural indices along the wetland-upland gradient. Thus, the direct gradient analysis graphs were used to determine the general location of the lower and upper bounds of the transition zone (i.e., between

the emergent aquatic zone and the low prairie or pasture zone). Subsequently, ordination (indirect gradient analysis) was used to quantitatively delimit more exact upper and lower bounds by graphically displaying the relationships among vegetation samples.

Additional Information

10. In addition to determining a suitable sampling methodology for study area wetlands, the project also yielded other basic information useful in the determination of wetland borders. This information base includes an extensive species list (160 species) and voucher specimens, data on the geographic diversity and vegetation composition of transition zones, a list of transition zone species, and information on the role of certain environmental factors (e.g., disturbance and topography) which fundamentally affect the nature of vegetation zones and transitions around wetlands.

11. In this report, testing and evaluation of the methodology are necessarily discussed first (Part II), followed by transition zone and wetland delineation (Part III). Part IV constitutes a general evaluation of the results and identifies future research needs. Characterization of sample wetlands and transects is in Appendix A. Appendix B includes direct gradient analysis graphs of species cover, vegetation structure, and species diversity for each sample transect. Appendix C lists the species encountered, their five-digit mnemonic code, and presence value (percentage of transects in which each species occurred).

PART II: METHODOLOGY TESTING AND EVALUATION

Testing

12. Methods were initially tested in late June 1979 at Buffalo Slough. Sampling experiments were performed to determine:

   a. Appropriate quadrat size for belt transect samples.

   b. Similarity of species' positions and interspersion along the transects as estimated by line-intercept and belt transect samples.

   c. Value of vertical structure estimates in delineation of transition zones.

   d. Relative time efficiency of belt transect, line-intercept, and cover board sampling techniques.

Quadrat size

13. Transect 01 was extended well into upland prairie (*Bouteloua curtipendula*, *Muhlenbergia cuspidata*) and emergent aquatic zones (*Scirpus validus*, *Typha angustifolia*) in order not to prejudge the location of the transition zone. Along the 55-m transect, contiguous rectangular-shaped quadrats 0.5 m by 1 m were laid out with the long axis perpendicular to the tape. No trees or large shrubs ≥ 1 cm dbh (diameter breast height) occurred along the transect; therefore, the quadrat width was not increased to accommodate larger plants. The 1-m width is maximum for efficient sampling of forbs and graminaceous plants that dominate the transect vegetation. The quadrat was, however, further subdivided into two smaller quadrats each 0.5 m wide, with one centered over the tape. The two quadrat sizes (0.25 and

0.50 m^2) enabled the assessment of local spatial variability near the transect as indicated by differences in species frequency and cover. Estimates of percent cover were made for each species in each 0.25-m^2 quadrat. The two estimates were averaged to compute percent cover in the 0.50-m^2 plots.

14. Fifty species occurred in the 0.50-m^2 plots, compared to 43 and 42 in the 0.25-m^2 plots. This represents about a 15 percent reduction in species number using the smaller quadrat size. The species not sampled in one or both of the pair of small quadrats included three transition zone species (*Bidens frondosa*, *Agropyron repens*, *Ambrosia trifida*) and twelve low- and mid-prairie species. These species were all infrequent along the transect, each occurring respectively in only 1, 1, and 3 percent of the quadrats. No emergent aquatic species were missing from either of the paired 0.25-m^2 plots.

15. A similar pattern occurred in transects 02 through 04, with differences in species number of approximately 15, 12, and 22 percent, respectively. Species not sampled in the smaller quadrats included several transition zone species (*Carex laeviconica*, *Lycopus americanus*, *Parietaria pennsylvanica*, and *Carex atherodes*) and a larger number of low- and mid-prairie species. The missing species were all rare along the transects, occurring in only 1 to 3 percent or tne 0.50-m^2 plots. Again, quadrat size did not affect species numbers in the emergent aquatic zone. The differences in species mean cover as estimated from 0.25- and 0.50-m^2 plots were rarely greater than 5 points, which is the inherent error in estimating cover in the field with

5 percent classes (Table 1). Although wooded transitions are uncommon in South Dakota wetlands, quadrat width needs to be increased when arboreal vegetation is encountered. Quadrats were widened to 6 m in transect 04 to sample _Fraxinus pennsylvanica_ trees.

16. In summary, there appears to be no strong advantage in using the larger 0.50-m^2 quadrat size for sampling along the transect. Mean cover estimates from both plot sizes were very similar and only a few uncommon species with minimal indicator value would be missed in the smaller quadrat. The large majority of these occurred in the low- and mid-prairie zones.

Line-intercept and belt transect comparisons

17. Species positions along the transect (i.e., distance between upper and lower bounds) were compared using the belt transect (0.50 m^2) and line-intercept methods (Figures 2 and 3). In the line-intercept method, a species was recorded as being present in a transect sub-unit (0.50 m long) if it touched the tape or if the plant was bisected by a vertical plane passing through the tape. Methods were compared by computing the distance between the upper and lower bounds of each species and expressing the line-intercept estimate as a percentage of the quadrat estimate. The species distance estimated by the line-intercept method would, of course, be equal to or less than, but never greater than, the distance estimated by the belt transect method. This is because the line-intercept sample occurred within the quadrat sample (i.e., the tape was the quadrat

Table 1

Comparison of Mean Cover by Species*

Species	Mean Cover A	Mean Cover C	Mean Cover B
Agropyron smithii	15.1	14.8	15.3
Ambrosia psilostachya	2.4	2.0	2.1
Andropogon gerardi	29.6	17.1	15.2
Artemisia ludoviciana	1.4	1.3	-
Bouteloua curtipendula	9.0	5.2	4.9
Cirsium arvense	8.8	7.0	6.8
Euphorbia esula	1.0	0.7	1.0
Helianthus rigidus	1.0	0.9	1.6
Lemna spp.	49.4	50.8	52.2
Lycopus asper	10.7	7.8	6.8
Melilotus spp.	11.7	11.0	11.2
Panicum virgatum	25.6	15.3	16.4
Phragmites communis	14.4	8.8	6.8
Poa pratensis	28.3	27.5	27.6
Rosa arkansana	9.1	6.1	5.4
Scolochloa festucacea	12.7	13.4	14.8
Sonchus arvensis	19.0	18.1	23.3
Spartina pectinata	4.6	3.2	1.8
Symphoricarpos occidentalis	12.8	9.2	11.9
Typha angustifolia	23.9	20.4	19.5

* Estimates from quadrats (occupied plots) of two sizes for transect 01. C quadrats (0.50 m^2) were subdivided into A (0.25 m^2) and B (0.25 m^2) quadrats along the sample transect. Species which occurred in <5 sample plots are excluded.

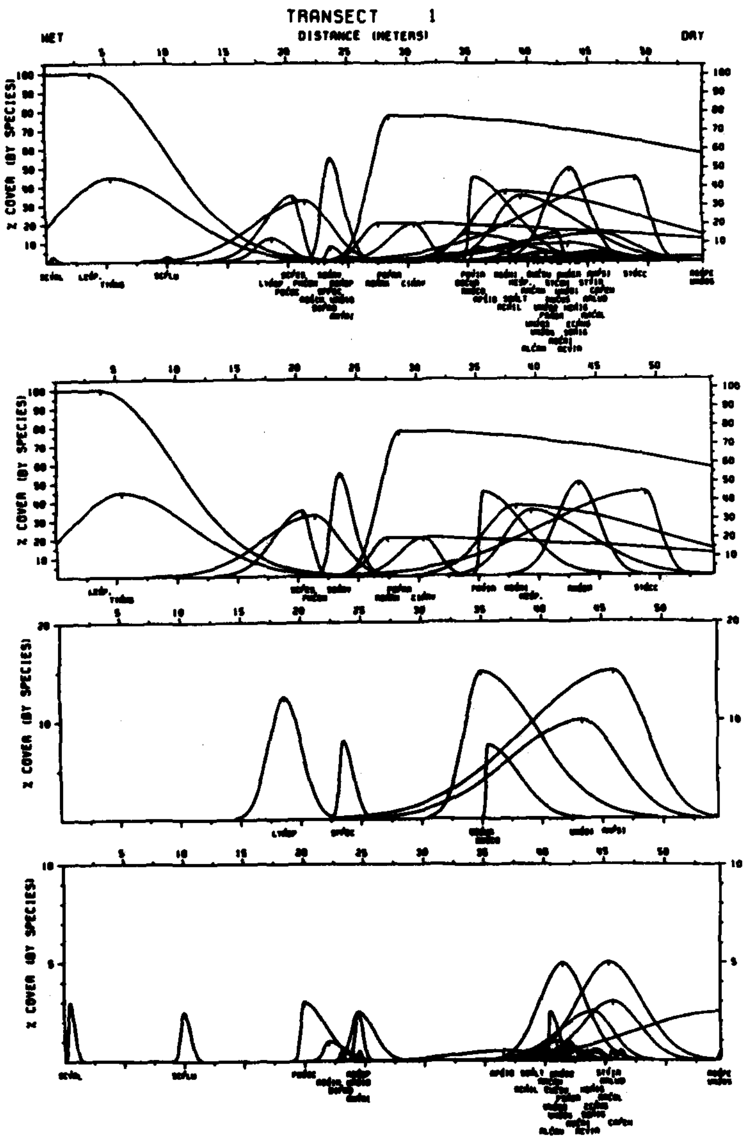

Figure 2. Cover by species (0.50-m^2 sample plots) along transect 01 at Buffalo Slough. Each half of the species cover curves was independently drawn to fit a standard normal distribution with 2 standard deviations. The end points of the distribution and the position of maximum cover are identical to field data. The top graph includes all species occurring along the transect, the second graph includes species with maximum cover values >30 percent, the third >5 percent, and the fourth $\leq$5 percent. Tick marks at the peak of each curve correspond directly below to a species mnemonic code. Where tick marks on curves are superimposed vertically, the mnemonic code nearest the x-axis corresponds to the curve of maximum height, and so on. See Appendix C for translation of mnemonic codes for species

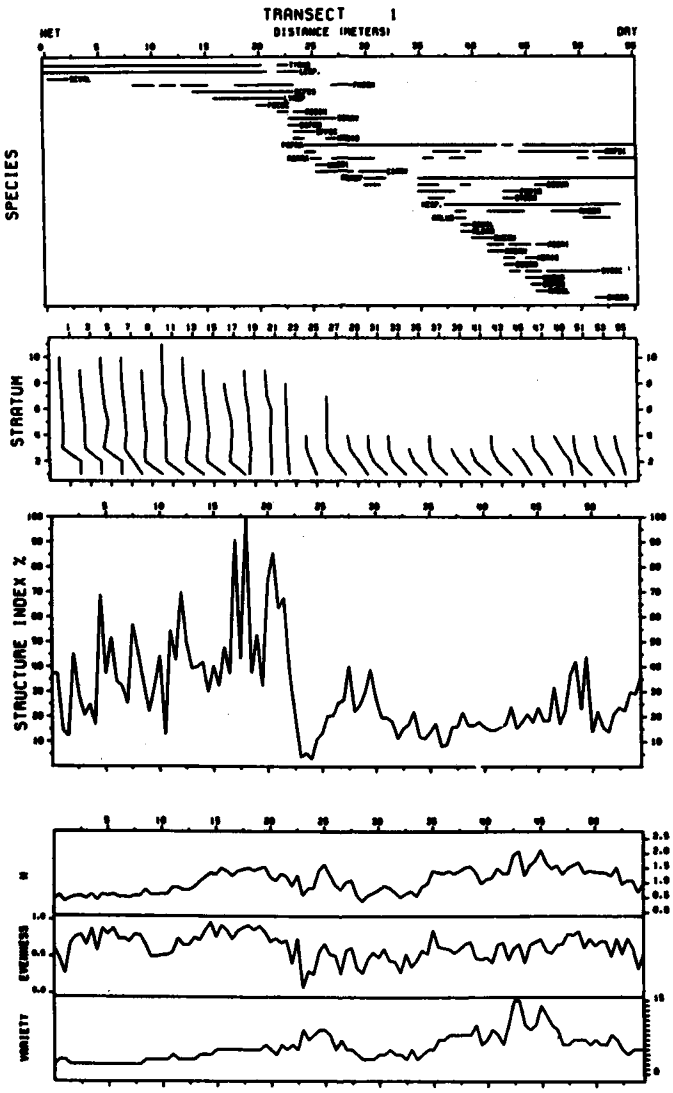

Figure 3. Distribution of species along transect 01 as estimated by line-intercept data (top graph); cover profiles (second graph, averaged over 2-m segments); structural index (third graph, see text); and H' diversity, evenness, and variety (bottom graph). See Appendix C for translation of mnemonic codes for species

midline). Also, the percentage of gaps (samples between the lower and upper bounds in which the species was absent) was estimated for each method.

18. Thirty-four of the fifty species (68 percent) that occurred in the belt transect were also sampled with the line-intercept technique. Some of the missing species were frequent along the transect but did not exhibit high cover values. The number of species present in the line-intercept data, expressed as a percentage of the number in the quadrat data (transects 01-13), ranged from 62 to 86 percent with a mean of 72 percent. Thus, the line-intercept method samples far fewer species than the quadrat method (either 0.25- or 0.50-m^2 quadrat sizes), and some of the species not sampled in the line-intercept are potentially important in defining zones and transitions.

19. Greater differences between the two techniques occurred in their respective estimates of species positions. For example, in transect 01 the distances estimated by both methods were identical in 11 of 34 cases, while in the remaining 23 cases the distances were estimated to be shorter with the line-intercept technique (8 to 98 percent shorter). Of these 23 species, 10 were estimated to occupy transect lengths $\leq$ 50 percent of that estimated by the quadrat techniques. Average line-intercept distance was 62 percent of the distance estimated by quadrat data. Moreover, the line-intercept data set included a greater proportion of gaps compared to the belt transect method (39 vs. 31 percent, respectively).

20. Thus, the uncertainty in the spatial position of

species is high as estimated by the line-intercept method. A difference of several metres on either end of species distributions was not uncommon. In the case of transect 01, this difference represented approximately 25 percent of the width of the transition zone.

21. In summary, the line-intercept method was far less effective in representing the spatial relationships of species and their interspersion along the transect compared to quadrat data. Also, a number of important species were not sampled by the line-intercept method because of their patchy spatial distributions. The deficiencies are serious enough that the transition zone location could be in considerable error. The absence of some indicator species in the sample could cause additional error in delineating the upper and lower borders of the transition zone.

Cover board technique

22. Vertical structure of the vegetation was measured with a cover board 0.5 m wide and 0.20 m high. The board was positioned at each 0.5-m segment of the transect and total cover (percent) for each 20-cm stratum was estimated from a sighting distance of 0.5 m. The board was loosely attached to a tubular metal pruning pole with u-bolts so that it could be raised and lowered during sampling (Figure 4). Utility of structural data was evaluated by constructing structural profiles and by devising a structural index which integrates cover density and height. Structural profiles were constructed by plotting percent cover

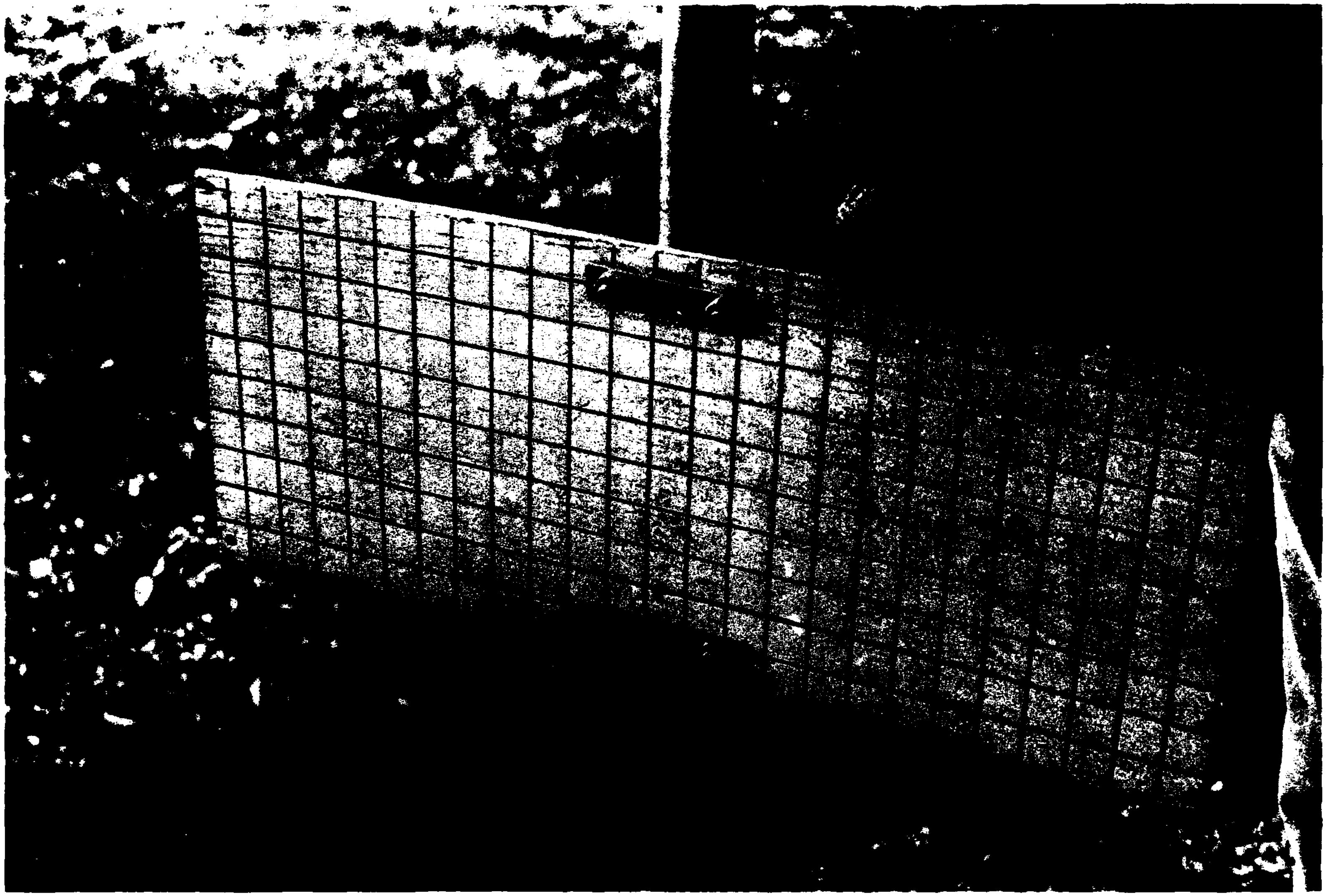

Figure 4. Cover board used to measure vertical structure of vegetation

along the x-axis and height along the y-axis (Figure 3). The structure profiles represent the average of four contiguous 0.5-m samples along the transect (i.e., 2-m segments). The structural index I produces a single value at each sample point and is computed as:

$$I = C \times S$$

where

C= the sum of the cover estimates at each sampling point

S= the total number of occupied strata

The index values I were scaled to range from 0 to 100 (Figure 3).

23. Both techniques reflect the strong structural changes that occur along the wetland-upland gradient. The index I clearly indicates a strong transition in structure at 22 to 24 m (Figure 3). This transition coincides with a change from tall emergent aquatic plants (*Typha*, *Phragmites*, and *Scolochloa*) to relatively short transition zone vegetation (*Poa*, *Sonchus*, and *Agropyron*). The transition is most sharply demarcated by I , but the structural profiles also indicate a substantial change in vegetation height at about the same transect position.

24. In transect 01, and in a large proportion of the other transects studied, tall emergent aquatic plants bordered the transition zone; therefore, the transition between emergent aquatic and wetland transition zones (i.e., the lower border of the transition zone) can often be defined by vegetation structure, although the species composition changes sharply as

well (Figure 2). The structural index clearly and quantitatively reflects this strong change in vegetation structure for transect 01. The structural measurements have greatest value in the delineation of the lower border of the transition zone in study area wetlands. The upper border of the transition zone is less differentiated structurally from the low prairie than by vegetation composition (Figure 3).

Time efficiency

25. Rankings. The line-intercept method was the most time efficient (i.e., average time spent per metre of transect), followed by vertical structural measurements, and finally by the belt transect (Table 2). Efficiency improved with time for all techniques. Time estimates for 0.25-m^2 quadrats (belt transect; transects 07-04) sampled early in the study were similar to sampling times for 0.50-m^2 quadrats (transects 05-20) sampled later in the study.

26. Combining the adjusted efficiency for the belt transect method with the 2.5-min/m estimate for vertical structure measurements yields a total average efficiency of about 9 min/m. This is excluding the line-intercept technique, which, despite its high efficiency, is not recommended here as a component of the wetland transition sampling methodology for reasons discussed earlier. This efficiency multiplied by the average length of the 20 transects (21 m) yields an average sampling time per transect of 3.2 hr.

Table 2

Time Efficiencies of Belt Transect, Line-Intercept, and Vertical Structure Sampling Methods

Site	Sampling Method: Belt Transect	Line Intercept	Vertical Structure
Transects 01-04*			
Range	5.0-8.0	2.0-3.0	2.0-4.0
Mean	6.4	2.6	2.9
Transects 05-20**			
Range	2.9-8.0	1.3-3.2+	1.3-3.8
Mean	6.4	2.0+	2.5

Note: Units are min/m of transect; transects were sampled in chronological order.

* 0.25-m^2 plots.

** 0.50-m^2 plots.

\+ Data collected only along transects 05 through 13.

27. Streamlined methodology. The average time estimate of 9 min/m is based on sampling both horizontal cover by species and vertical structure at every 0.5-m segment of the transect. Sampling efficiency can, however, be improved considerably by sampling only along critical portions of the transect, i.e., across lower and upper transition zone borders. Unless the investigator is interested in vegetation gradients within the transition zone itself, there is little need to sample across it. Experience indicates that the general locations of transition zone borders are often discernable with simple field observation. In such cases, structural sampling could be confined to the region of the lower transition where it has proven to be most effective, and cover by species could be determined from quadrats placed across both transitions. This streamlined technique would require only about half (or even less) the number of samples; therefore, the time efficiency could be reduced to 1 to 2 hr per transect. The streamlined technique should be applicable to a large proportion of study area wetlands. However, in some cases, the structural differences between wetland and prairie are not pronounced (primarily in temporary wetlands) and a larger proportion of the total transect would need to be sampled.

Evaluation

28. The recommended field sampling methodology to determine transition zone borders in study area wetlands based on the evaluation of available methods is discussed in the following paragraphs.

29. Transects should be laid out perpendicular to topographic contours and should extend into the emergent aquatic zone on one end and into low prairie, pasture, or cropland on the other. The transect should be defined by a steel tape. Sampling should be done in late July-August when most species are flowering or in fruit and when structural differences along transects are maximum.

30. Both compositional and structural measurements should be made along the transect.

a. Composition--cover by species of forbs, graminaceous plants, small shrubs, and woody seedlings should be determined from contiguous 0.25-m^2 sample plots (0.50 by 0.50 m) with the transect tape as the quadrat midline. If the transect runs through woods or brushy vegetation, the quadrat width should be increased to 3 to 5 m for small trees and large shrubs and to 6 to 8 m for trees, assuming that the sample area remains spatially homogeneous. Wooded wetland transition zones are uncommon in the study area except on floodplains. Of the wetlands studied, randomly placed transects would have occurred in wooded conditions no more than 1 in 50 times.

b. Structure--the cover board method to estimate vertical structure of vegetation should also be used at 0.5-m intervals. A sliding board (20 by 50 cm) generally works well, but a single large board (e.g.,

0.5 by 2 m) marked off into strata may work better in emergent aquatic vegetation where raising and lowering the sliding board is sometimes difficult. The cover board should be white in color with a coarse grid of dark lines to assist in estimating the proportion of the board covered by vegetation. Total cover at each stratum is estimated visually from a distance of 0.5 m. Increased time efficiency can be obtained by increasing stratum height (e.g., from 20 to 30 cm) and thereby reducing the number of necessary cover estimates.

31. The streamlined method of placing samples can be used along transects where the general location of upper and lower transition zone borders can be determined in the field; otherwise, continuous data should be collected. With the streamlined method, two sampling zones need to be determined, one encompassing the lower and one the upper border of the transition zone. The lower sampling zone should include a portion of emergent aquatic and transition zones and would typically be several metres wide. Indicator species for emergent aquatic, transition, and low prairie zones are given later in this report. Both horizontal and vertical cover as discussed above should be estimated along the lower sampling zone. The upper sampling zone typically exhibits increasing cover of mesic-dry prairie species (e.g., *Agropyron smithii*, *Andropogon gerardi* and *Panicum virgatum*) and decreasing cover of broad-leaved ruderal species (e.g., *Cirsium arvense* and *Sonchus arvensis*) and weedy grasses (e.g., *Poa pratensis* and *Agropyron repens*). This upper

transition changes more gradually than the lower transition and, hence, the sample zone may be wider. Enough samples should be taken to ensure that the natural border occurs within them. Data from each sampling zone shall be analyzed by ordination to determine if more specific upper and lower boundaries can be identified.

PART III: TRANSITION ZONE AND WETLAND DELINEATION

Identifying Specific Borders

Definition

32. The transition zone is defined here as occurring between the emergent aquatic zone and the low- to mid-prairie zone or its man-disturbed equivalent (e.g., pasture, cropland). It corresponds most closely to the meadow category (primarily high meadow) of Dix and Smeins (1967). As discussed in the previous section, its general upper and lower borders can be determined from direct gradient analysis graphs of species cover and vertical structure. If the borders are generally discernable in the field, sampling efficiency can be improved considerably by confining samples to these two sampling zones. This section deals with the problem of refining the transitions into specific borders through the application of ordination techniques.

Dichotomies in composition

33. A primary basis for identifying a specific border in each transition would be the presence of a strong compositional dichotomy between adjacent vegetation samples. The occurrence of a dichotomy would likely be matched by an underlying dichotomy in the environment, such as a sharp change in soil characteristics (e.g., soil texture) or topography. If vegetation gradients are continuous, the task of identifying borders would be more difficult and decisions would have to be based on what is known about the ecological relationships of species.

Ordination

34. Ordination (Swan, Dix, and Wehrhahn 1969) was used to

aid in the identification of compositional discontinuities among samples. This technique was designed to arrange samples in n-dimensional space based on their compositional similarities. It cannot be satisfactorily applied to the entire wetland-upland gradient because of the large number of zero comparisons between transect samples. For example, samples at the ends of the gradient typically have no species in common (e.g., emergent aquatics vs. prairie grasses) in which case their index of similarity (Euclidean index) would be 0. These zero comparisons cause considerable distortion in the model (Swan 1970) such that the spatial arrangement of samples does not always reflect actual ecological similarity. In some cases, where the percentage of zero values in the similarity matrix is high, the most dissimilar stands (i.e., those at opposite ends of the environmental gradient) are placed close together, erroneously indicating high similarity.

35. One remedy is to ordinate only a subset of the transect data thereby greatly minimizing the number of zero values. Therefore, ordination models for transects were based on samples from lower and upper transitions. Each transition represents only a small range of the complete environmental gradient, and zero comparisons are few. Two models were produced, one each for lower and upper transitions.

Representative Transects

36. Space does not allow for the detailed discussion of ordination results of all 20 transects; therefore, several

transects were selected to represent the range of conditions found in study wetlands. These include transects 01 and 03 at Buffalo Slough, transect 09 at Anderson Slough, transect 12 at Engelhardt Slough, transect 14 at Platte Lake and transects 16 and 20 at Ordway Prairie. These transects represent a wide range of disturbance conditions and wetland types.

Transect 01, Buffalo Slough

37. Buffalo Slough is a permanent, slightly brackish wetland. Ordination models for transect 01 were based on samples from lower (20-24 m) and upper (32-36 m) transitions. The model for the lower transition (Figure 5) indicates a strong dichotomy in composition at 22.5 m. The 22.5-m sample is shown as distinct from samples below it and above it.

38. Field data indicate that the 22.5-m sample marks a clear shift from shallow-water emergent aquatic vegetation (e.g., *Phragmites*) to short ruderal vegetation dominated by *Sonchus* (Table 3). From 22.0 to 22.5 m, the relative cover of *Phragmites* and *Typha* decreased by a factor of 2 while the relative cover of *Sonchus* doubled and three additional ruderal species appeared (*Bidens*, *Ambrosia*, and *Urtica*). Thus the lower side of 22.5 m is dominated by emergent aquatic species and the upper side by broad-leaved ruderals. The ordination model identified a sharp compositional dichotomy, which is a strong basis for identifying it as a border between emergent aquatic and transition zones.

39. Inspection of direct gradient analysis graphs identified the upper transition as occurring from 32 to 36 m. The ordination model based on this set of samples (Figure 5)

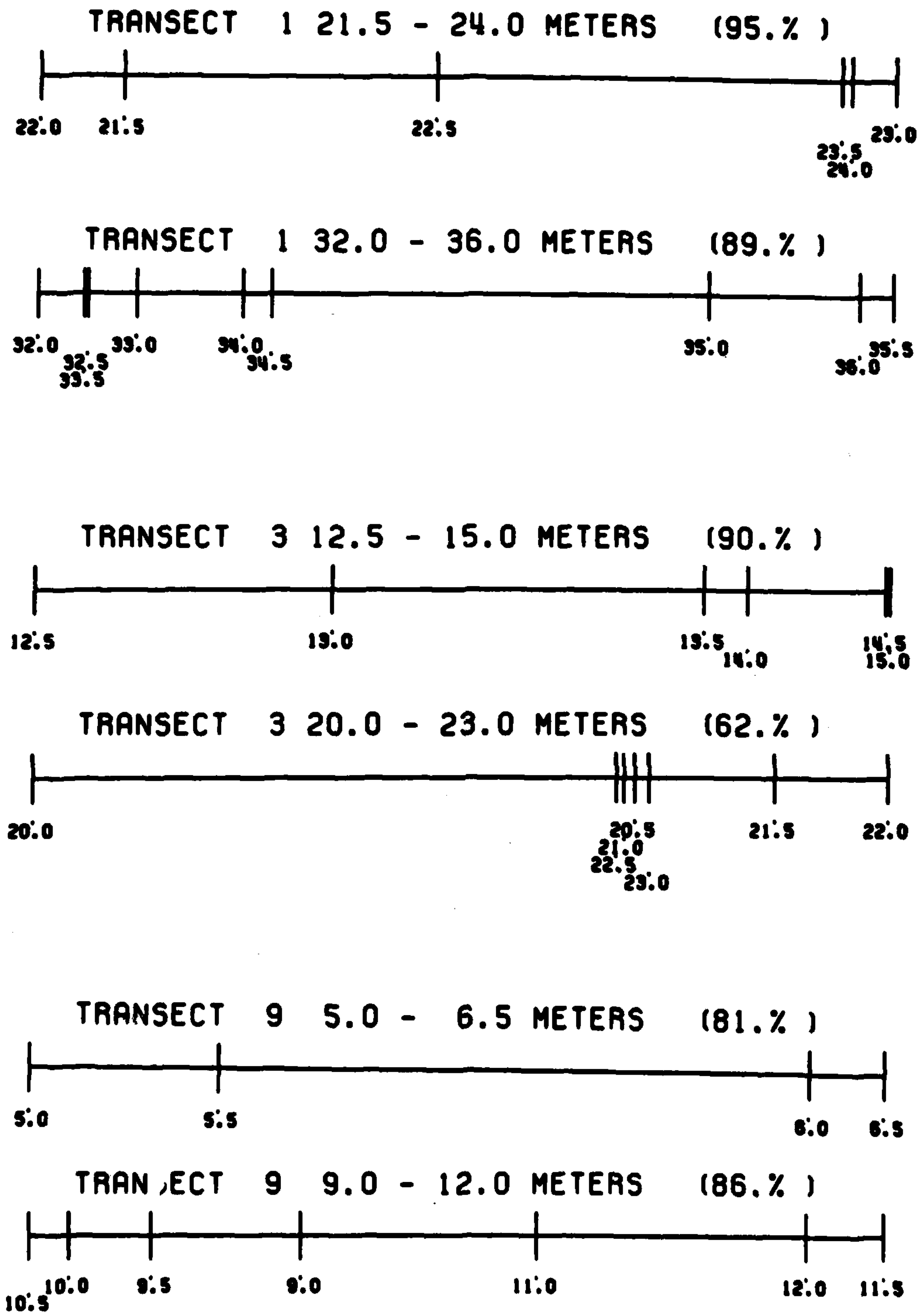

Figure 5. Ordination models (x-axis only) for upper and lower transitions of transects 01, 03, and 09 following the technique of Swan, Dix, and Wehrhahn (1969)

Table 3

Relative Cover by Species*

Species	Sample Distance, m 22.0	22.5	23.0	34.0	34.5	35.0	35.5
Typha angustifolia	8	3	1				
Lemna spp.	3	5					
Phragmites communis	75	39	1				
Scolochloa festucacea	9						
Lycopus asper		13					
Aster simplex	3		1				
Sonchus arvensis	2	40	89				
Bidens frondosa			1				
Spartina pectinata			3				
Symphoricarpos occidentalis				1			
Ambrosia psilostachya			1				
Urtica dioica			1				
Poa pratensis				60	57	26	15
Agropyron smithii				33	34	18	9
Bouteloua curtipendula				5	7	22	9
Muhlenbergia cuspidata				1			
Stipa comata					1		
Rosa arkansana				1	1		
Melilotus spp.					1	1	
Panicum virgatum					33	55	
Helianthus rigidus						1	
Andropogon scoparius						9	

* In percent, transect 01 at Buffalo Slough. Lower transition = 22.0, 22.5, and 23.0 m; upper transition = 34.0, 34.5, 35.0, and 35.5 m.

indicated a sharp dichotomy in vegetation composition between 34.5 and 35.0 m. Field data show that the dichotomy is caused by a decrease in relative cover of Poa pratensis and a substantial increase in two native prairie species, Bouteloua curtipendula and Panicum virgatum. Relative cover of upland prairie grasses (excluding Poa) was 42 percent at 34.5 m and 73 percent at 35.0 m. The change toward prairie vegetation continued at 35.5 m with 82 percent cover by upland prairie species. Thus, the dichotomy exposed by ordination reflects a strong shift from samples predominated by Poa pratensis, the dominant species in the transition zone, to predominance by low prairie grasses. The last representative of broad-leaved ruderals (Cirsium arvense) dropped out at 33.5 m, about 1 m below the dichotomy.

40. The 34.5- to 35.0-m dichotomy appears to be a natural border between transition zone and mesic prairie vegetation. It therefore qualifies as the upper border of the transition zone; however, it also appears to define the upper margin of significant influence from the wetland. Frequent variation in water table depth and surface flooding at the wetland margin are primarily responsible for the large number of ruderals in the transition zone. A variable hydrologic regime in the transition zone causes high plant mortality, which provides unoccupied sites for colonization by ruderals. The early spring shoreline was densely colonized by ruderals.

41. The transition zone itself as defined here must be considered part of the wetland due to the obvious disturbance by changing water levels and siltation. The upper border as defined

appears to be largely outside this zone of disturbance. It therefore represents a relatively stable wetland border compared to the lower transition zone border (e.g., 22.5 m) which probably changes position annually, depending on water levels, wave action, and scouring by ice in early spring. Dix and Smeins (1967) place the upland-lowland border at the interface of low prairie and high meadow zones. They describe soils in the low prairie as at least moderately well drained and rarely inundated, but, if inundated, only for very brief periods. The water table is usually below the rooting depth of most plants in the low prairie. Dominants listed by Dix and Smeins (1967) are Andropogon gerardi, A. scoparius, Sorghastrum nutans, and Spartina pectinata.

42. The transition zone as defined here by ordination begins at 22.5 m and ends at 34.5 to 35 m, a distance of about 12 m. As discussed earlier, broad-leaved and graminaceous ruderals dominate the vegetation of the transition zone (Table 4). The emergent aquatic zone is dominated by Typha, Scolochloa, Phragmites, Lemna, and Lycopus, while the zone above the wetland border is dominated by prairie grasses (Panicum, Agropyron and Bouteloua) and small shrubs (e.g., Symphoricarpos) (Table 4). Pocket gopher burrowing is partly responsible for the abundance of several species of ruderals (Melilotus, Euphorbia, Ambrosia) in the prairie zone. Of the six species which attain their maximum cover in the transition zone, five are confined to it (Sonchus, Spartina, Agropyron, Urtica, Cirsium) and hence can tentatively serve as transition zone indicators (Table 4). Species diversity (H') per sample in emergent aquatic and

Table 4

Zone of Maximum Percent Cover for Species

in Transect 01 at Buffalo Slough

Species	Emergent Aquatic	Transition	Low to Mid Prairie
Typha angustifolia	X		
Lemna spp.	X		
Scirpus validus	X		
Phragmites communis	X		
Scirpus fluviatilis	X		
Scolochloa festucacea	X		
Lycopus asper	X		
Polygonum coccineum	X		
Sonchus arvensis		X	
Spartina pectinata		X	
Poa pratensis		X	
Agropyron repens		X	
Urtica dioica		X	
Cirsium arvense		X	
Symphoricarpos occidentalis			X
Ambrosia psilostachya			X
Agropyron smithii			X
Bouteloua curtipendula			X
Asclepias speciosa			X
Melilotus spp.			X
Muhlenbergia cuspidata			X
Stipa comata			X
Andropogon gerardi			X

* Excluding species with 1 percent maximum.

transition zones is comparable while diversity in the prairie zone is considerably higher. All three zones are discernable in Figure 6.

Transect 03, Buffalo Slough

43. Ordination models of lower and upper transitions along transect 03 indicate compositional dichotomies at 13.0 m and at 20.0 to 20.5 m (Figure 5) resulting in a zone width of about 7 m. The narrower transition zone compared to transect 01 (12 m) appears to be the result of steeper topography (average slope of 27 percent vs. 12 percent in transect 01). The lower dichotomy at 13.0 m is caused primarily by a rapid increase in the cover of Poa pratensis and Euphorbia esula and by a concomitant decrease in Spartina pectinata (Figure 7). The upper discontinuity at 20.0 to 20.5 m is the product of a substantial decline in Poa pratensis cover and an increase in the cover of Bouteloua curtipendula, the predominant upland grass species on the transect.

44. The vegetation defining the borders of transect 03 is similar to that of transect 01. However, one important distinction is the position of Spartina pectinata. In transect 03 this species occurs with emergent aquatics (Scolochloa, Phragmites, and Typha) and its peak cover is within the emergent aquatic zone. In transect 01, its lowest position coincides with the beginning of the transition zone and therefore its peak cover occurs within the transition zone. Such differences indicate that zonal affinities shift occasionally within the same wetland. More study of basic wetland autecology is needed before the

Figure 6. Photograph of the eastern shoreline (looking north) of Buffalo Slough. The transition zone appears as a dark zone of short, matted vegetation bordered on the wetland side by taller, emergent aquatic vegetation and on the upland side by taller lighter colored prairie vegetation

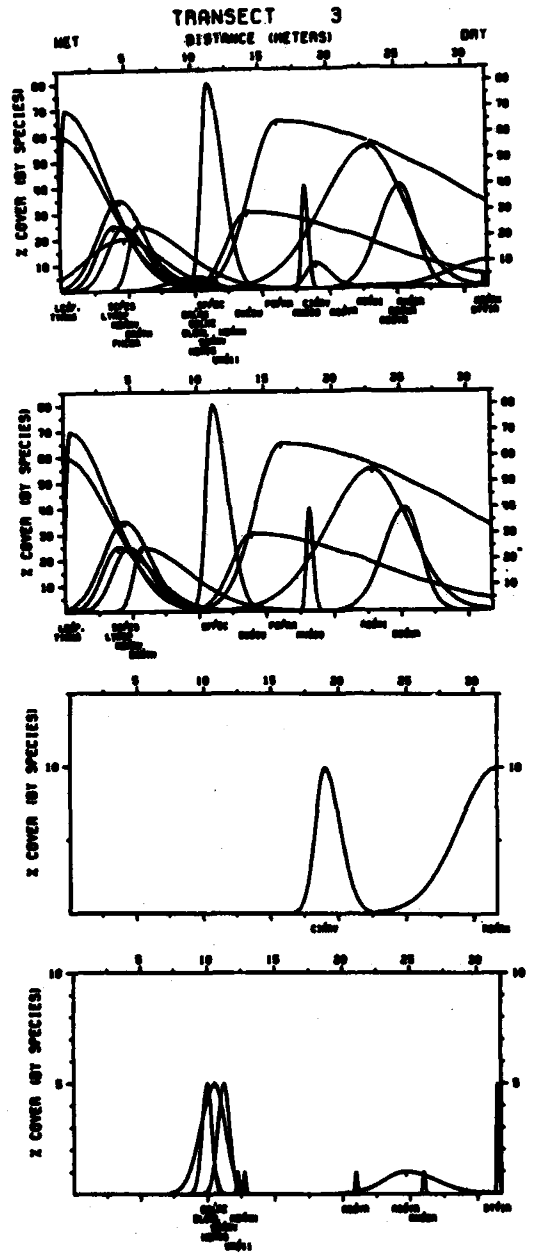

Figure 7. Cover by species along transect 03 at Buffalo Slough. The top graph includes all species occurring along the transect, the second graph includes species with maximum cover values >30 percent, the third >5 percent, and the fourth ≤5 percent. Tick marks at the peak of each curve correspond directly below to a species mnemonic code. Where tick marks on curves are superimposed vertically, the mnemonic code nearest the x-axis corresponds to the curve of maximum height, and so on. See Appendix C for translation of mnemonic codes for species

environmental basis for such shifts can be understood.

Transect 09, Anderson Slough

45. Anderson Slough is a semipermanent, slightly brackish wetland. Strongest discontinuities within each transition occurs at 4.5 to 6.0 m and 10.5 to 11.0 m (Figure 5). The transition zone is narrow (4 m) but still bounded by emergent aquatics below and upland prairie above (Figure 8). The dichotomy at 5.5 to 6.0 m is again primarily due to an extremely sharp increase in *Poa pratensis* (2.5 percent cover at 5.5 m compared to 87.5 percent cover at 6.0 m). Distribution of emergent aquatics (*Scirpus* and *Scolochloa*) essentially ends at 5.5 m. The upper border is equally distinct, at 10.5 m the cover of *Andropogon gerardi* is 0 while at 11.0 m it climbs to 60 percent.

46. *Poa pratensis* declines in relative cover with distance but still maintains high cover values throughout the uplands in mixture with numerous dry-mesic prairie grasses (e.g., *Stipa viridula*). It is especially common and abundant in the uplands of Anderson Slough, more so than around the other wetlands studied. In transect 10, *Poa* continues to dominate the vegetation of the uplands several hundred meters beyond the end of the transect. Its distribution cannot therefore always be used as an indicator of the transition zone; thus, the presence of other species intermixed with *Poa* must be relied upon to identify the wetland borders.

Transect 12, Engelhardt Slough

47. Engelhardt Slough is a freshwater, semipermanent

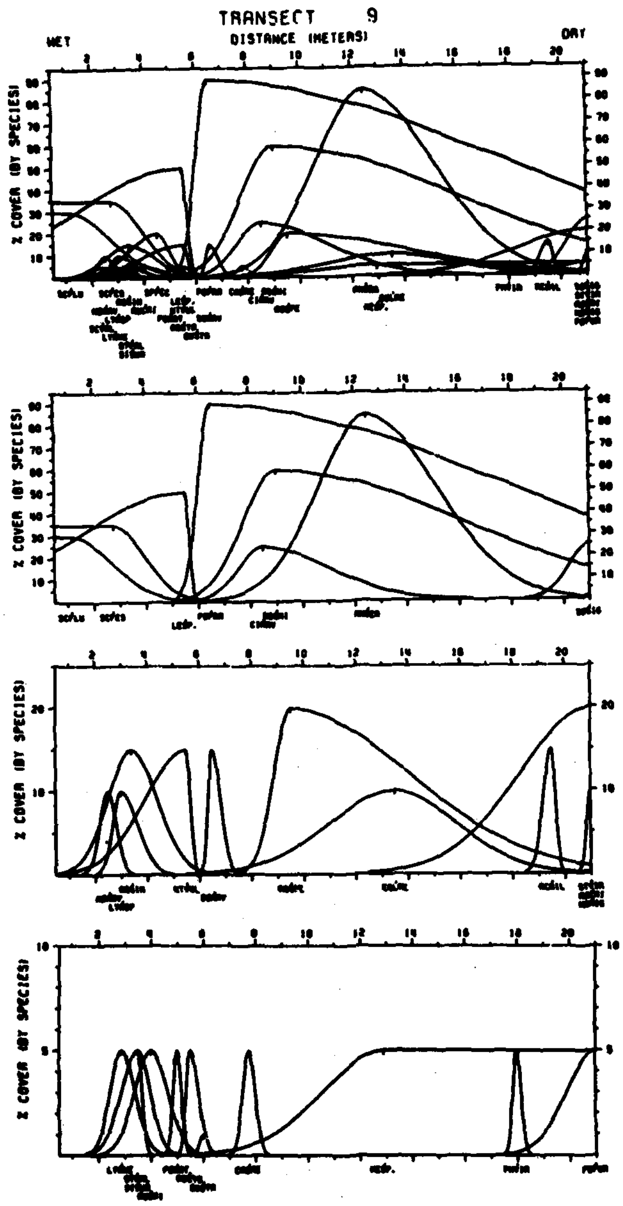

Figure 8. Cover by species along transect 09 at Anderson Slough. The top graph includes all species occurring along the transect, the second graph includes species with maximum cover values >30 percent, the third >5 percent, and the fourth ≤5 percent. Tick marks at the peak of each curve correspond directly below to a species mnemonic code. Where tick marks on curves are superimposed vertically, the mnemonic code nearest the x-axis corresponds to the curve of maximum height, and so on. See Appendix C for translation of mnemonic codes for species

wetland. Ordination identified transition zone borders at 12.5 to 13.0 m and at 18.0 m (Figure 9), a width of approximately 5 m. The lower border is sharp, caused primarily by a sharp increase in Poa pratensis and a concomitant decline in Phalaris arundinacea and Polygonum coccineum (Figure 10). Spartina pectinata intermixes with Phalaris and therefore occurs primarily within the emergent aquatic zone. The upper border at 18.0 m was due to the occurrence of Bromus inermis. The separation of samples at 18.5 and 19.0 m (Figure 9) was due to a large increase in Bromus cover (not a gain or loss of species) and therefore does not define a vegetation community boundary.

48. In transect 12, the upper border of the transition zone occurs at the point where Poa has declined to near 0 and Bromus inermis has begun to increase towards the uplands. Each species forms a spatially distinct zone with little overlap. However, in other transects (e.g., 11 and 13), Bromus and Poa occurred together and exhibit similar lower borders. Here, as in the case of Poa at Anderson Slough, other species growing with Poa and Bromus need to be utilized when defining the upper border of the transition zone. Bromus inermis is widely planted in the study area for hay and wildlife cover and to protect rights-of-way from erosion. It has an extremely wide ecological tolerance and therefore is not always a sensitive indicator of environment. Other more sensitive species do grow within the Bromus cover and those should be utilized when defining the upper transition zone border.

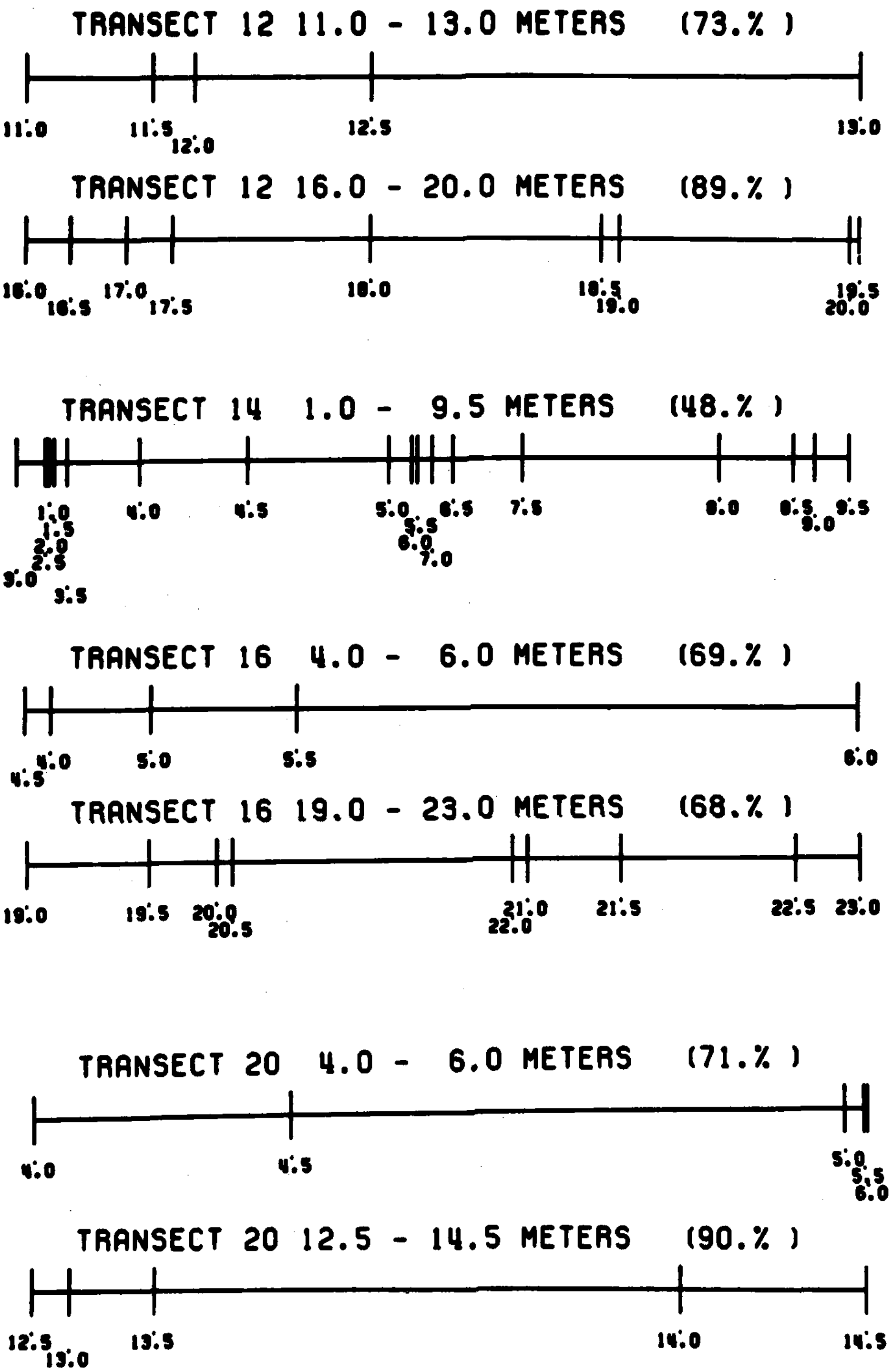

Figure 9. Ordination models (x-axis only) for upper and lower transitions of transects 12, 14, 16, and 20 following the technique of Swan, Dix, and Wehrhahn (1969)

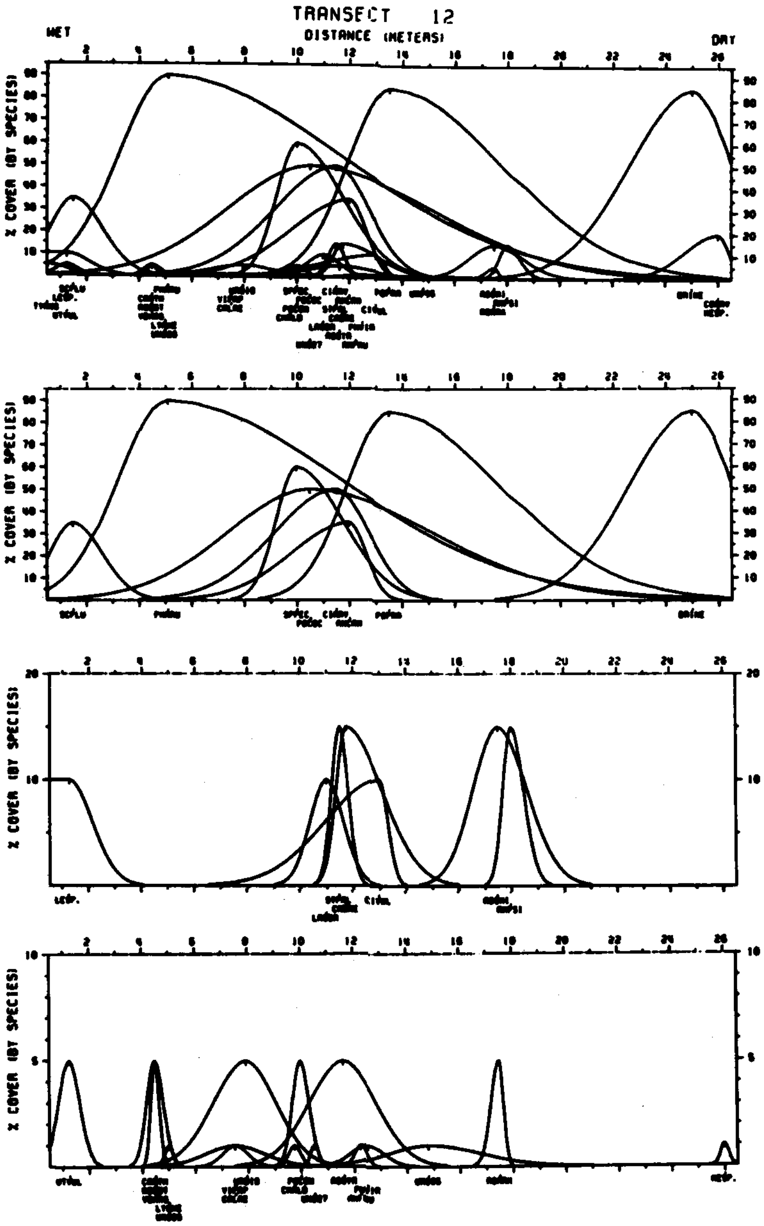

Figure 10. Cover by species along transect 12 at Engelhardt Slough. The top graph includes all species occurring along the transect, the second graph includes species with maximum cover values >30 percent, the third >5 percent, and the fourth ≤5 percent. Tick marks at the peak of each curve correspond directly below to a species mnemonic code. Where tick marks on curves are superimposed vertically, the mnemonic code nearest the x-axis corresponds to the curve of maximum height, and so on. See Appendix C for translation of mnemonic codes for species

Transect 14, Platte Lake

49. Platte Lake is a freshwater, semipermanent wetland. Ecological conditions along transects at Platte Lake are in marked contrast to those discussed earlier. A major difference is the more rapid drawdown rate at Platte Lake enabling colonization of the emergent aquatic zone by ruderals. Many ruderals more typical of the transition zone on other transects are intermixed with emergent aquatic species (e.g., Scirpus fluviatilis) on exposed silt. The upper transition is equally difficult to identify from direct gradient analysis graphs and therefore all samples were included in the ordination. The transect is relatively short (10 m) and contains many species with broad ecological amplitudes; therefore, the proportion of zero values is small compared to longer transects.

50. The model indicates dichotomies at 3.5 to 5.0 m and 7.5 to 8.0 m (Figure 9). The lower dichotomy marks the point of strong decline of Riccia and a sharp increase in Bidens frondosa, the primary ruderal growing on the exposed silt (Figure 11). However, this border is likely to be highly changeable seasonally, depending on drawdown rate. A border here would also incorrectly bisect the distribution of Scirpus fluviatilis, a common emergent aquatic species in the study area.

51. The 7.5- to 8.0-m dichtomy marks the end of the distribution of Scirpus fluviatilis, Stachys palustris, Mentha arvensis and ruderals growing on the exposed silt (Bidens, Ambrosia, and Helianthus). This major dichotomy marks a more permanent lower transition zone border, at least on an annual

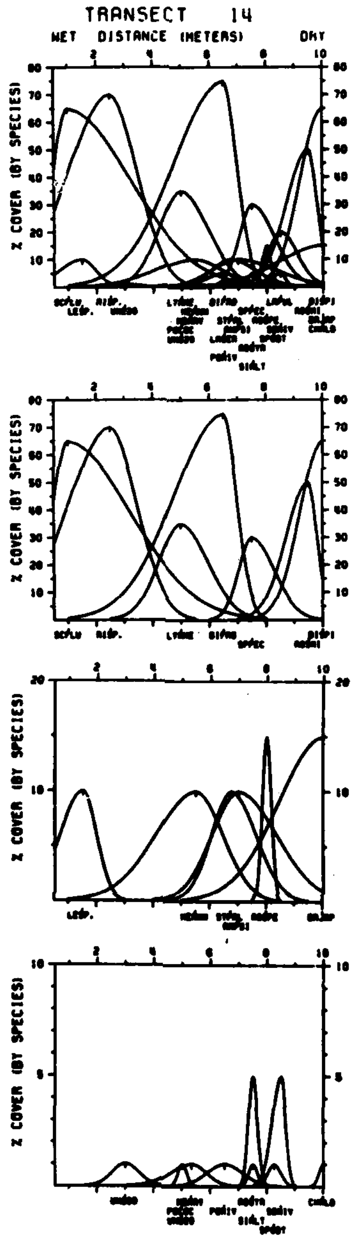

Figure 11. Cover by species along transect 14 at Platte Lake. The top graph includes all species occurring along the transect, the second graph includes species with maximum cover values >30 percent, the third >5 percent, and the fourth ≤5 percent. Tick marks at the peak of each curve correspond directly below to a species mnemonic code. Where tick marks on curves are superimposed vertically, the mnemonic code nearest the x-axis corresponds to the curve of maximum height, and so on. See Appendix C for translation of mnemonic codes for species

basis. Interestingly, the distribution of several mesic upland species (e.g., Agropyron smithii and Asclepias speciosa) also begins at 8.0 m, intermixed with Spartina pectinata. The ordination does not indicate any strong dichotomy beyond 8.0 m. Therefore, specific delineation of the upper border remains problematic, although it occurs somewhere between 8 and 10 m. The diverse mixture of ruderals and prairie perennials clearly complicates delineation of the wetland border. It could be argued that there exists little or no transition zone and that the emergent aquatic zone abuts the uplands. The wetland border would therefore coincide more or less with the edge of the emergent aquatic zone. The error in placing the wetland border would not be large (maximum of 2 m), but clearly more study of this type of transition would be necessary to define a more specific border.

Transect 16, Ordway Prairie Pond 1

52. Pond 1 is a moderately brackish, permanent wetland. The major discontinuities in the ordination models for transect 16 are at 5.5 to 6.0 m and at 20.5 to 21.0 m, a distance of about 14 m (Figure 9). The lower transition is especially sharp; the distributions of emergent aquatic species (Scirpus, Eleocharis, Alisma) and other salt-tolerant species end at 5.5 m (Figure 12). A nearly monotypic zone of Hordeum jubatum begins at 6.0 m (Figure 13). Zonation around this brackish, permanent wetland is the most distinct of any of the wetlands studied. The upper border marks the beginning of Panicum virgatum, the most abundant native prairie grass in the transect. Interestingly, two

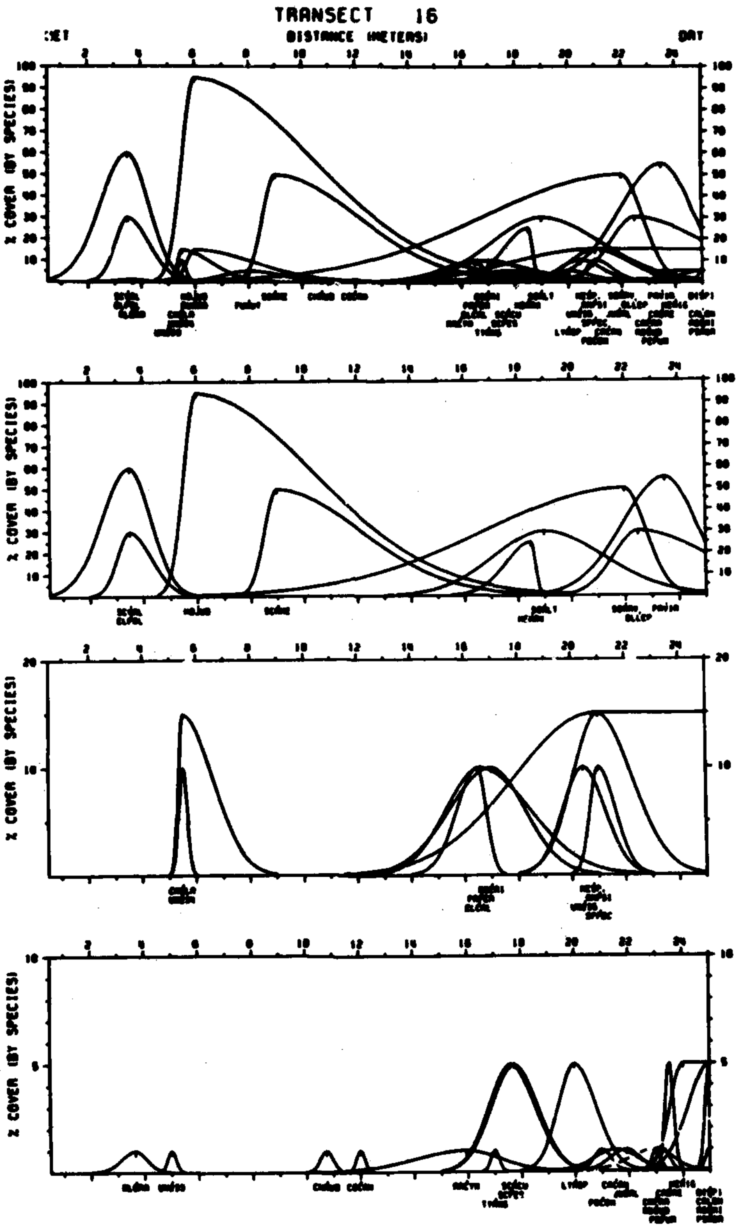

Figure 12. Cover by species along transect 16 at pond 1 at Ordway Prairie. The top graph includes all species occurring along the transect, the second graph includes species with maximum cover values >30 percent, the third >5 percent, and the fourth ≤5 percent. Tick marks at the peak of each curve correspond directly below to a species mnemonic code. Where tick marks on curves are superimposed vertically, the mnemonic code nearest the x-axis corresponds to the curve of maximum height, and so on. See Appendix C for translation of mnemonic codes for species

Figure 13. Pond 1 at Ordway Prairie. White-topped zone is *Hordeum jubatum* bounded on the wetland side by *Scirpus*. The pole supporting the wetland end of the sample tape is visible in the open water zone. Photograph taken in early August 1979

ruderals (Sonchus and Ambrosia) typically confined to transition zones (e.g., transect 01) occur significantly beyond the transition zone and within the upland prairie. With the border at 21.0 m, Spartina pectinata occurs within both the transition zone and the upland prairie zone, which is different from its typical position near the lower transition zone border along most other transects.

Transect 20, Ordway Prairie Pond 3

53. Pond 3 is a seasonal wetland. Ordination models for transect 20 (Figure 9) show dichotomies at 4.5 to 5.0 m and at 13.5 to 14.0 m, resulting in a transition zone width of about 9 m. Again, the lower border is distinct, marking the change from emergent aquatics (Sparganium and Alisma) to a dense zone of Calamagrostis inexpansa and Eleocharis palustris (Figure 14). The upper border at 14.0 m marks the influx of native prairie grasses (Andropogon gerardi and A. scoparius). Agropyron smithii, which often occurs in the transition zones of other transects, appears 1 m above the beginning of A. gerardi. Transect 20 is shown in Figure 15.

Conclusions

54. Ordination analysis is generally effective in portraying vegetational discontinuities along transitions in the seven representative transects. Transitions are sharper at the lower border of the transition zone compared to the upper border. In many of the transects, the major discontinuity among samples from the lower transition is caused by a rapid increase in the

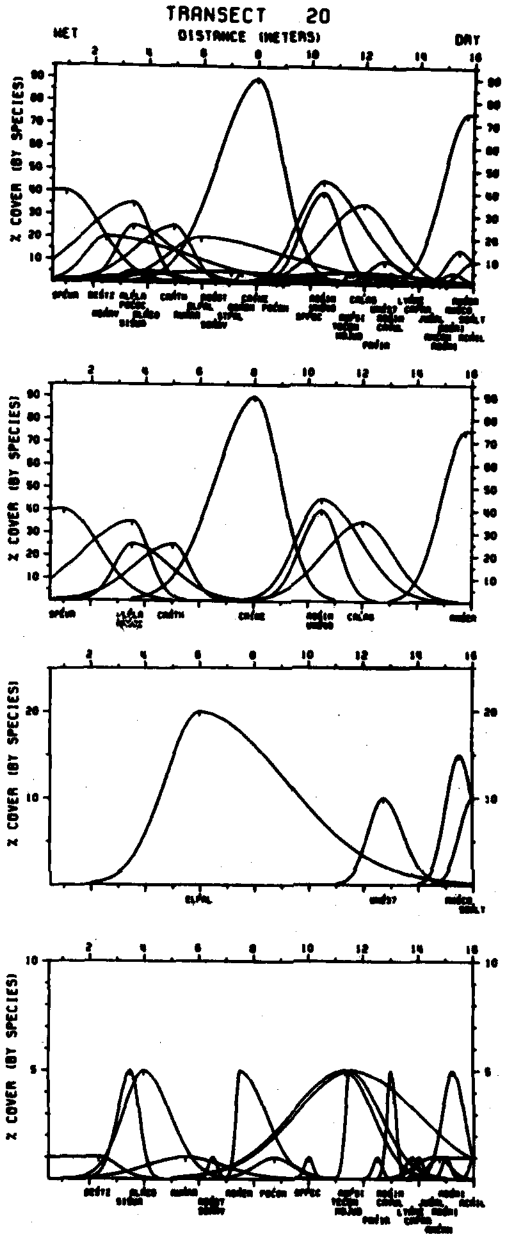

Figure 14. Cover by species along transect 20 at pond 3 at Ordway Prairie. The top graph includes all species occurring along the transect, the second graph includes species with maximum cover values >30 percent, the third >5 percent, and the fourth ≤5 percent. Tick marks at the peak of each curve correspond directly below to a species mnemonic code. Where tick marks on curves are superimposed vertically, the mnemonic code nearest the x-axis corresponds to the curve of maximum height, and so on. See Appendix C for translation of mnemonic codes for species

Figure 15. Pond 3 at Ordway Prairie. Wetland center is dominated by Sparganium eurycarpum, transition zone by Calamagrostis inexpansa, and low prairie by Andropogon gerardi. Photograph taken in early August 1979

cover of Poa pratensis and broad-leaved ruderals with a concomitant decrease in the cover of emergent aquatic species (e.g., Typha, Phragmites, and Scolochloa). The most prevalent dichotomy in composition at the upper transition occurs where Poa pratensis declines significantly (or reaches zero) and a number of low prairie grasses and forbs appear. The major upper and lower discontinuities as defined by ordination generally correspond to major changes in plant community composition. The lower border frequently marks a sharp structural change from tall emergent aquatic species to low-growing transition zone species. The major advantage of ordination analysis is that it enables a quantitative delineation of upper and lower transition zone borders. The width of the transition zones from representative wetlands ranges from near 0 to 14 m, with an average near 7 m.

55. The upper border of the transition zone as defined earlier is also the most probable wetland border. On the wetland side of the border, a large number of ruderal species typical of moist, disturbed environments occur. Wide seasonal and annual fluctuations in water regime are typical of wetlands in the northern Great Plains. Colonization of the transition zone by ruderals is undoubtedly facilitated by (a) high plant mortality caused by the widely fluctuating groundwater regime, and (b) erosion of existing vegetation during high water in the spring and the subsequent deposition of silt during seasonal drawdown. The upper border would appear to be relatively stable over time, but no time-series data are available. In contrast,

the lower transition zone border is highly changeable annually and its position depends in large measure on water levels in early spring.

56. The most difficult wetlands in which to delineate transition zone borders are those disturbed by heavy grazing or planted to pasture. Heavy grazing increases the number of ruderals along the entire gradient and confuses the location of the wetland borders. Pasture grasses (e.g., *Bromus inermis*), like ruderals, have extremely broad ecological tolerances and generally serve as poor indicators of environment. Many potential indicator species are eliminated due to the intense competition from *Bromus* and other tame grasses. There is considerable variability in the affinities of species to major vegetation zones along the wetland-upland gradient. For example, *Spartina pectinata* occurs in emergent aquatic, transition, and low prairie zones, although occurring most frequently in the transition zone (Table 5). Dix and Smeins (1967) also note that *Spartina pectinata* crosses the division between uplands and lowlands (i.e., border between meadow and low prairie) and exhibits high frequency values on both sides.

57. The indicator approach has great potential value in delineating borders in disturbed or revegetated sites. However, more study is needed before species can be accurately ranked based on their value as an indicator of a given zone or transition.

Table 5

Preliminary Estimate of Zonal Positions for Species Encountered in Representative Wetland Transects*

Emergent Aquatic Zone

Alopecurus aequalis	Phalaris arundinacea
Alisma plantago-aquatica	Phragmites communis
Anemone canadensis**	Polygonum coccineum
Aster simplex**	Rumex crispus
Carex atherodes	Scirpus fluviatilis
Carex lasiocarpa**	Scirpus validus
Carex laeviconica	Sium suave
Eleocharis calva**	Scolochloa festucacea
Eleocharis palustris**	Sparganium eurycarpum
Lactuca serriola**	Spartina pectinata**
Lemna spp.	Stachys palustris
Lycopus americanus	Typha angustifolia
Lycopus asper	Urtica dioica**
Mentha arvensis	Utricularia vulgaris

Transition Zone

Agropyron smithii**	Helianthus maxmiliani
Ambrosia psilostachya**	Lactuca serriola**
Anemone canadensis**	Melilotus spp.**
Asclepias speciosa	Panicum perlongum
Asclepias syriaca**	Poa pratensis
Aster ericoides**	Puccinellia nuttalliana
Aster simplex**	Ranunculus cymbalaria
Calamagrostis inexpansa	Rumex maritimus
Carex brevior	Solidago altissima**
Carex lasiocarpa**	Sonchus arvensis
Chenopodium glaucum	Spartina pectinata**
Cirsium arvense**	Symphoricarpos occidentalis**
Cirsium vulgare	Teucrium canadense
Eleocharis calva**	Urtica dioica**
Eleocharis palustris**	Viola papilionacea
Hordeum jubatum	

Low to Mid-Prairie Zone

Agropyron smithii**	Equisetum laevigatum
Ambrosia psilostachya**	Glycyrrhiza lepidota
Andropogon gerardi	Helianthus rigidus
Andropogon scoparius	Juncus balticus

(Continued)

*Transects 01, 03, 09, 12, 16, and 20.

**Species typically occurred in two zones.

Table 5 (Concluded)

Low to Mid-Prairie Zone (Continued)	
Artemisia ludoviciana	*Melilotus spp.***
*Asclepias syriaca***	*Muhlenbergia cuspidata*
*Aster ericoides***	*Panicum virgatum*
Bouteloua curtipendula	*Psoralea argophylla*
Bromus inermis	*Rosa arkansana*
*Cirsium arvense***	*Solidago gigantea*
Convolvulus arvensis	*Solidago altissima***
Echinacea angustifolia	*Stipa comata*
Euphorbia esula	*Stipa viridula*
	*Symphoricarpos occidentalis**

* Transects 01, 03, 09, 12, 16, and 20.

** Species typically occurred in two zones.

PART IV: NEEDED RESEARCH

58. The results described in this report are based on vegetation patterns as they occurred during the 1979 field season. Water levels in eastern South Dakota were extremely high due to heavy spring and summer rains. Precipitation at Sioux Falls during 1979 was about 12 cm above average. Buffalo Slough, near Sioux Falls, was reportedly almost dry in 1977, but began to fill again in 1978. Water depth at the beginning of the 1979 field season was reportedly higher than average. After sampling in late June-early July, 10 to 12 cm of rain fell in a few hours and the surface water level increased 0.5 to 0.7 m, covering a significant portion of the transition zone and in places inundating the margin of the low prairie. Thus, over a 3 year period, midsummer water levels in the middle of the wetland ranged from near zero in 1977 to 2.5 to 3.0 m in 1979. This represents an estimated distance of about 100 m between 1977 and 1979 shorelines.

59. The effect of widely fluctuating water levels on vegetation zonation around the margin of wetlands is known to be considerable (Stewart and Kantrud 1971). The degree to which transition zone borders change is unknown in the absence of quantitative data on the temporal position of zones and transitions. The lower aquatic border would be expected to exhibit less spatial stability than the upper border (wetland border). However, without knowledge of the temporal stability of the wetland border, it would be difficult to support on scientific grounds the 1979 wetland border as a permanent

border. Remeasurement of the 20 permanently marked transects is currently under way and will enable periodic, accurate assessment of the stability of the wetland border in a variety of wetland conditions.

60. Given the expected annual variation in wetland borders as defined by vegetation and the known difficulty in delineating wetland borders where grazing has been heavy or where native communities have been replaced by tame pasture grasses, a search is needed for more stable parameters than are currently being used as surrogate variables to define wetland borders. Other studies (e.g., Dix and Smeins (1967)) have shown that certain soil parameters (e.g., conductivity of extracts and texture) correlate strongly with the wetland-upland moisture gradient. It is likely that discontinuities in these or other variables may at least be partly responsible for the observed discontinuities in vegetation and they would likely be more stable spatially and temporally. Detailed analyses of soil characteristics are currently being conducted simultaneously with the remeasurement of vegetation along the permanent transects.

61. In summary, the research conducted during the first year of the project has identified, through experimentation, a field sampling methodology that is efficient and that accurately represents the spatial positions of species along the wetland-upland gradient. Additionally, the combined use of direct gradient analysis and ordination can assist in the quantitative identification of wetland borders for a given year. The integration of extensive wetland vegetation data now in hand with

new information on spatial and temporal variability in vegetation and environment should provide a superior methodology to delineate wetland-upland borders, compared to the use of a single year of vegetation data alone.

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APPENDIX A: WETLAND TRANSECT CHARACTERISTICS

Transect identification number: 01
Watershed: Buffalo Slough
General location: long. 96°55'50", lat. 43°52'54"; Colton, S. Dak. Quadrangle (USGS, 7.5 min, 1968); Chester Township, Lake County.
Specific location: east margin of Buffalo Slough; upper (landward) end of transect is an estimated 22 m from a small Russian olive tree on an azimuth of ca. 0 deg (from tree to transect); transect runs 55 m on an azimuth of 250 deg from upper to lower end; permanent markers at meters -1.0 (lower end), 24.0, and 55.0 (upper end).
Water regime: surface water column 40 cm deep at meter 0.0 and 0 cm deep at meter 23.75 (exposed soil-standing water interface); salinity 0.5 ppt, specific conductance 1050 μmhos, salinity class: slightly brackish.
Slope inclination along transect:

Transect segment, m	Slope, %
0-24.0	water
24.0-34.3	12
34.3-39.2	27
39.2-50.0	36
50.0-53.0	25
53.0-55.0	5

Disturbance: limited herbicide spraying by S. Dak. Game, Fish, and Parks Dept. to control leafy spurge and Canada thistle.
Number of plant species recorded along transect: 50
Sampling date: 26 June 1979
Vegetation sampling methods: line-intercept every 0.25 and 0.50 m; belt transect quadrat sizes: 0.25 and 0.50 m^2; cover board every 0.50 m.

Transect identification number: 02
Watershed: Buffalo Slough
General location: long. 96°55'59", lat. 43°52'06", Colton, S. Dak. Quadrangle (USGS, 7.5 min, 1968); Chester Township, Lake County.
Specific location: south margin of Buffalo Slough ; upper(landward) end of transect is 7.3 and 8.2 m from two adjacent fenceposts on azimuths of 305 and 0 deg, respectively (from fenceposts to transect); transect runs 26.8 m on an azimuth of 315 deg from upper to lower end; permanent markers at meters 0.0 (lower end), 6.0, and 26.8 (upper end).
Water regime: surface water column 16 cm deep at meter 0.0 and 0 cm deep at meter 6.5 (exposed soil-standing water interface); salinity 0.5 ppt, specific conductance 1050 μmhos, salinity class: slightly brackish.
Slope inclination along transect:

Transect segment, m	Slope, %
0-6.0	water
6.0-17.5	7
17.5-21.0	5
21.0-26.8	12

Disturbance: heavy grazing by domestic livestock.
Number of plant species recorded along transect: 41
Sampling date: 2 July 1979
Vegetation sampling methods: line intercept every 0.5 m; belt transect quadrat sizes: 0.25 and 0.50 m^2; cover board every 0.5 m.

Transect identification number: 03
Watershed: Buffalo Slough
General location: long. 96°55'59", lat. 43°52'28", Colton, S. Dak. Quadrangle (USGS, 7.5 min, 1968); Chester Township, Lake County.
Specific location: east margin of Buffalo Slough; upper (landward) end of transect is 25.5 m from a large green ash on an azimuth of 80 deg (from tree to transect); transect runs 32.5 m on an azimuth of 200 deg from upper to lower end; permanent markers at meters 0.0 (lower end) and 32.5 (upper end).

Water regime: surface water column 12 cm deep at meter 0.0 and 0 cm deep at meter 10.0 (exposed soil-standing water interface); salinity 0.5 ppt, specific conductance 1050 μmhos, salinity class: slightly brackish.
Slope inclination along transect:

Transect segment, m	Slope, %
0-10.00	water
10.00-13.00	6
13.00-16.75	14
16.75-19.50	23
19.50-23.75	43
23.75-28-00	37
28-00-30.25	22
30.25-32.50	9

Disturbance: limited herbicide spraying by S. Dak. Game, Fish, and Parks Dept. to control leafy spurge and Canada thistle.
Number of plant species recorded along transect: 26
Sampling date: 5 July 1979

Vegetation sampling methods: line-intercept every 0.50 m; belt transect quadrat sizes: 0.25 and 0.50 m^2; cover board every 0.50 m.

Wetland identification number: 04
Watershed: Buffalo Slough
General location: long. 96°55'59", lat. 43°52'29"; Colton, S. Dak. Quadrangle (USGS, 7.5 min, 1968); Chester Township, Lake County.
Specific location: east margin of Buffalo Slough; upper (landward) end of transect is 4.9 m and 5.5 m from two adjacent trees on azimuths of 145 and 255 deg, respectively (from trees to transect); transect runs 17.5 m on an azimuth of 190 deg from upper to lower end; permanent markers at meters 0.0 (lower end) and 17.5 (upper end).
Water regime: surface water column 18 cm deep at meter 0.0 and 0 cm deep at meter 17.5 (exposed soil-standing water interface); salinity 0.5 ppt, specific conductance 1050 μmhos, salinity class: fresh.
Slope inclination along transect:

Transect segment, m	Slope, %
0-6.6	water
6.6-8.7	8
8.7-11.8	11
11.8-15.0	10
15.0-16.5	22
16.5-17.5	9

Disturbance: none recently
Number of plant species along transect: 39
Sampling date: 6 July 1979
Vegetation sampling methods: line-intercept every 0.5 m; belt transect quadrat sizes: 0.25 and 0.50 m^2; cover board every 0.50 m.

Transect identification number: 05
Watershed: Buffalo Slough
General location: long. 96°55'59", lat. 43°52'26": Colton, S. Dak. Quadrangle (USGS, 7.5 min, 1968); Chester Township, Lake County.
Specific location: east margin of Buffalo Slough; upper (landward) end of transect is 2.8 m from a green ash tree on an azimuth of 138 deg (from tree to transect); transect runs 15.5 m on an azimuth of 232 deg from upper to lower end; permanent markers at meters 0.0 (lower end), 6.0, and 15.5 (upper end).
Water regime: surface water column 13.5 cm deep at meter 0.0 and 0 cm deep at meter 6.0 (exposed soil-standing water interface); salinity 0.5 ppt, specific conductance 1050 μmhos, salinity class: slightly brackish.
Slope inclination along transect:

Transect segment, m	Slope, %
0-6.0	water
6.0-7.5	4
7.5-9.5	14
9.5-11.5	11
11.5-14.0	18
14.0-15.5	26

Disturbance: limited herbicide spraying by S. Dak. Game, Fish, and Parks Dept. to control leafy spurge and Canada thistle.
Number of plant species recorded along transect: 24
Sampling date: 10 July 1979
Vegetation sampling methods: line-intercept every 0.50 m; belt transect quadrat size: 0.50 m^2; cover board every 0.50 m.

Transect identification number: 06
Watershed: Buffalo Slough
General location: long. 96°55'59", lat. 43°52'18"; Colton, S. Dak. Quadrangle (USGS, 7.5 m, 1968); Chester Township, Lake County.
Specific location: east margin of Buffalo Slough; upper (landward) end of transect is 23.25 m from a Russian olive tree on an azimuth of 172 deg (from tree to transect); transect runs 14.5 m on an azimuth of 239 deg from upper to lower end; permanent markers at meters 0.0 (lower end), 10.0, and 14.5 (upper end).
Water regime: surface water column 10.5 cm deep at meter 0.0 and 0 cm deep at meter 4.0 (exposed soil-standing water interface); salinity 0.5 ppt, specific conductance 1050 μmhos, salinity class: slightly brackish.
Slope inclination along transect:

Transect segment, m	Slope, %
0-4.00	water
4.00-7.00	0
7.00-9.75	6
9.75-13.50	15
13.50-14.50	17

Disturbance: limited herbicide spraying by S. Dak. Game, Fish, and Parks Dept. to control leafy spurge and Canada thistle.
Number of plant species recorded along transect: 29
Sampling date: 10 July 1979
Vegetation sampling methods: line-intercept every 0.50 m; belt transect quadrat size: 0.50 m^2; cover board every 0.50 m.

Transect identification number: 07
Watershed: Buffalo Slough
General Location: long. 96°55'59", lat. 43°52'08"; Colton, S. Dak. Quadrangle (USGS, 7.5 min, 1968); Chester Township, Lake County.
Specific location: east margin of Buffalo Slough; upper end of transect is 33.5 m from an elm tree on an azimuth of 3 deg (from tree to transect); transect runs 17.5 m on an azimuth of 263 deg from upper to lower end; permanent markers at meters 0.0 (lower end) and 17.5 (upper end).
Water regime: surface water column is 7.5 cm deep at meter 0.0 and 0 cm deep at meter 4.5 (exposed soil-standing water interface); salinity 0.5 ppt, specific conductance 1050 µmhos, salinity class: slightly brackish.
Slope inclination along transect:

Transect segment, m	Slope, %
0.0-5.0	water
5.0-9.0	11
9.0-11.5	13
11.5-15.5	16
15.5-17.5	14

Disturbance: limited herbicide spraying by S. Dak. Game, Fish, and Parks Dept. to control leafy spurge and Canada thistle.
Number of plant species recorded along transect: 28
Sampling date: 11 July 1979
Vegetation sampling methods: line-intercept every 0.50 m; belt transect quadrat size: 0.50 m^2; cover board every 0.50 m.

Transect identification number: 08
Watershed: Anderson Slough
General location: long. 96°52'07", lat. 43°52'06"; Colton, S. Dak. Quadrangle (USGS, 7.5 min, 1968); Lynn Township, Moody County.
Specific location: south margin of Anderson Slough upper (landward) end of transect is 2.1 m and 22.5 m from two adjacent elm trees on azimuths of 60 deg and 208 deg, respectively (from trees to transect); transect runs 19.5 m on an azimuth of 322 deg from upper to lower end; permanent markers at meters 0.0 (lower end) and 19.5 (upper end).
Water regime: surface water column 37 cm deep at meter 0.0 and 0 cm deep at meter 5.5 (exposed soil-standing water interface); salinity 0.5 ppt, specific conductance 1050 µmhos, salinity class: slightly brackish.
Slope inclination along transect:

Transect segment, m	Slope, %
0-5.5	water
5.5-9.5	15
9.5-13.0	15
13.0-15.5	21
15.5-18.0	17
18.0-19.5	17

Disturbance: limited herbicide spraying by S. Dak. Game, Fish, and Parks Dept. to control leafy spurge and Canada thistle.
Number of plant species observed along transect: 15
Sampling date: 12 July 1979
Vegetation sampling methods: line-intercept every 0.50 m; belt transect quadrat size: 0.50 m^2; cover board every 0.5 m.

Transect identification number: 09
Watershed: Anderson Slough
General location: long. 96°52'12", lat. 43°52'06"; Colton, S. Dak. Quadrangle (USGS, 7.5 min, 1968); Lynn Township, Moody County.
Specific location: southwest margin of Anderson Slough; upper (landward) end of transect is 10.75 m from a juniper tree on an azimuth of 250 deg (from tree to transect); transect runs 25.5 m on an azimuth of 50 deg from upper to lower end; permanent markers at meters 0.0 (lower end) and 25.5 (upper end).
Water regime: surface water column 47.5 cm deep at meter 0.0 and 0 cm deep at meter 5.5 (exposed soil-standing water interface); salinity 0.5 ppt, specific conductance 1050 μmhos, salinity class: slightly brackish.
Slope inclination along transect:

Transect segment, m	Slope, %
0-5.5	water
5.5-6.0	45
6.0-8.0	38
8.0-12.5	12
12.5-13.0	19
13.0-18.0	26
18.0-21.0	39
21.0-24.5	29
24.5-25.5	24

Disturbance: limited herbicide spraying by S. Dak. Game, Fish, and Parks Dept. to control leafy spurge and Canada thistle.
Number of plant species recorded along transect: 32
Sampling date: 13 July 1979
Vegetation sampling methods: line-intercept every 0.50 m; belt transect qradrat size: 0.50 m^2; cover board every 0.50 m.

Transect identification number: 10
Watershed: Anderson Slough
General location: long. 96°52'14", lat. 43°52'06"; Colton, S. Dak. Quadrangle (USGS, 7.5 min, 1968); Lynn Township, Moody County.
Specific location: southwest margin of Anderson Slough; upper (landward) end of transect is 19.5 m from a juniper tree (most northerly tree of planting on marsh side) on an azimuth of 274 deg (from tree to transect); transect runs 20.0 m on an azimuth of 302.5 deg from upper to lower end; permanent markers at meters 0.0 (lower end) and 18.3 (near upper end).
Water regime: surface water column 39 cm deep at meter 0.0 and 0 cm deep at meter 5.75 (exposed soil-standing water interface); salinity 0.5 ppt, specific conductance 1050 µmhos, salinity class: slightly brackish.
Slope inclination along transect:

Transect segment, m	Slope, %
0-5.75	water
5.75-8.00	7
8.00-9.50	-
9.50-11.00	7
11.00-14.00	7
14.00-17.20	12
17.20-18.25	27
18.25-20.00	5

Disturbance: limited herbicide spraying by S. Dak. Game, Fish, and Parks Dept. to control leafy spurge and Canada thistle.
Number of plant species recorded along transect: 31
Sampling date: 16 July 1979.
Vegetation sampling methods: line-intercept every 0.50 m; belt transect quadrat size: 0.50 m^2; cover board every 0.50 m.

Transect identification number: 11
Watershed: Englehardt Slough
General location: long. 96°07'16", lat. 43°34'55"; Grass Lake, S. Dak. Quadrangle (USGS, 7.5 min, 1964); Wellington Township, McCook County.
Specific location: south margin of Engelhardt Slough; upper (landward) end of transect is on a small point 2 m from a grassy road; transect runs 16.0 m on an azimuth of 340 deg from upper to lower end; permanent markers at meters 0.0 (lower end) and 15.8 (near upper end).
Water regime: surface water column 33 cm deep at meter 0.0 and 0 cm deep at meter 3.5 (exposed soil-standing water interface); salinity <0.5 ppt; specific conductance 500 μmhos, salinity class: fresh.
Slope inclination along transect:

Transect segment, m	Slope, %
0-4.2	water
4.2-5.8	16
5.8-8.3	4
8.3-10.6	31
10.6-12.8	58
12.8-15.0	29
15.0-16.0	11

Disturbance: none recently
Number of plant species along transect: 27
Sampling date: 17 July 1979.
Vegetation sampling methods: line-intercept every 0.50 m; belt transect quadrat size: 0.50 m^2; cover board every 0.50 m.

Transect identification number: 12
Watershed: Engelhardt Slough
General location: long. 97°07'12", lat. 43°34"55';
Grass Lake, S. Dak. Quadrangle (USGS, 7.5 min., 1964); Wellington Township, McCook County.
Specific location: south margin of Engelhardt Slough; upper (landward) end of transect is 5.2 m from the 17th post on an azimuth of 325 deg (from post to transect); transect runs 26.9 m on an azimuth of 322 deg from upper to lower end; permanent markers at meters 0.0 (lower end) and 26.9 (upper end).
Water regime: surface water column 23 cm deep at meter 0.0 and 0 cm deep at meter 3.0 (exposed soil-standing water interface); salinity <0.5 ppt; specific conductance 500 μmhos, salinity class: fresh.
Slope inclination along transect:

Transect segment, m	Slope, %
0-2.7	water
2.7-4.4	9
4.4-9.9	5
9.9-12.4	5
12.4-15.5	10
15.5-17.6	23
17.6-18.4	15
18.4-22.2	6
22.2-24.5	19
24.5-26.5	2

Disturbance: none recently
Number of plant species recorded along transect: 35
Sampling date: 18 July 1979
Vegetation sampling methods: line-intercept every 0.50 m; belt transect quadrat size: 0.50 m^2; cover board every 0.5 m.

Transect identification number: 13
Watershed: Engelhardt Slough
General location: long. 97°07'24", lat. 43°34'55"; Grass Lake, S. Dak. Quadrangle (USGS, 7.5 min, 1964); Wellington Township, McCook County.
Specific location: south margin of Engelhardt Slough; upper (landward) end of transect is 22.7 m from an ash tree on an azimuth of 208 deg (from tree to transect); transect runs 23.2 m on an azimuth of 355 deg from upper to lower end; permanent markers at meters 0.0 (lower end) and 23.2 (upper end).
Water regime: surface water column is 27 cm deep at meter 0.0 and 0 cm deep at meter 4.0 (exposed soil-standing water interface); salinity <0.5 ppt, specific conductance 500 μmhos, salinity class: fresh.
Slope inclination along transect:

Transect segment, m	Slope, %
0-4.5	water
4.5-6.0	20
6.0-9.8	7
9.8-13.0	4
13.0-14.7	18
14.7-17.3	16
17.3-18.9	12
18.9-21.9	9
21.9-23.2	14

Disturbance: none recently
Number of plant species recorded along transect: 35
Sampling date: 18 July 1979
Vegetation sampling methods: line-intercept every 0.5 m; belt transect quadrat size: 0.50 m^2; cover board every 0.50 m.

Transect identification number: 14
Watershed: Platte Lake
General location: Aurora County, South Dakota (no USGS 7.5 min topographic map exists for the area).
Specific location: northwest corner of Platte Lake; upper (landward) end of transect is an estimated 30 m south of the ditch along shoreline; transect runs 10.25 m on an azimuth of 125 deg from upper to lower end; permanent markers at meters 0.0 (lower end) and 10.25 (upper end).
Water regime: surface water column is 0 cm deep at meter 0.0; salinity <0.5 ppt, specific conductance 485 μmhos, salinity class: fresh.
Slope inclination along transect:

Transect segment, m	Slope, %
0-3.6	2
3.6-5.6	20
5.6-7.9	23
7.9-8.8	25
8.8-10.25	2

Disturbance: upper prairie portion mowed.
Number of plant species recorded along transect: 25
Sampling date: 19 July 1979
Vegetation sampling methods: Belt transect quadrat size: 0.50 m^2; cover board every 0.50 m.

Transect identification number: 15
Watershed: Platte Lake
General location: Aurora County, South Dakota (no USGS 7.5 min topographic map exists for the area).
Specific location: northwest corner of Platte Lake; upper (landward) end of transect is an estimated 60 m north of fence corner and 4.7 m from a Russian olive tree on an azimuth of 105 deg (from tree to transect); transect runs 18.0 m on an azimuth of 81 deg from upper to lower end; permanent markers at meters 0.0 (lower end) and 16.0 (near upper end).
Water regime: surface water column is 0 cm deep at meter 0.0; salinity <0.5 ppt, specific conductance 485 µmhos, salinity class: fresh.
Slope inclination along transect:

Transect segment, m	Slope, %
0-6.0	3
6.0-13.0	6
13.0-14.4	16
14.4-16.1	16
16.1-16.9	45
16.9-18.0	4

Disturbance: upper prairie portion mowed.
Number of plant species recorded along transect: 45
Sampling date: 23 July 1979
Vegetation sampling methods: Belt transect quadrat size: 0.50 m^2; cover board every 0.50 m.

Transect identification number: 16
Watershed: Ordway Prairie Pond No. 1 (specific wetland marked on aerial photograph)
General location: McPherson County, South Dakota (no USGS 7.5 min topographic map exists for the area).
Specific location: northwest corner of Pond No. 1; transect runs 28.5 m on an azimuth of 122 deg from upper to lower end; permanent markers at meters 0.0 (lower end) and 25.0 (near upper end).
Water regime: surface water column is 15 cm deep at meter 0.0 and 0 cm deep at meter 2.8 (exposed soil-standing water interface); salinity 2.5 ppt, specific conductance 4300 μmhos; salinity class: moderately brackish.
Slope inclination along transect:

Transect segment, m	Slope, %
0-2.8	water
2.8-7.3	5
7.3-8.5	9
8.5-14.4	8
14.4-17.6	9
17.6-20.3	12
20.3-21.9	12
21.9-24.0	13
24.0-25.0	2

Disturbance: light grazing by cattle and buffalo.
Number of plant species recorded along transect: 41
Sampling date: 23 July 1979
Vegetation sampling methods: Belt transect quadrat size: 0.50 m^2; cover board every 0.50 m.

Transect identification number: 17
Watershed: Ordway Prairie Pond No. 1 (specific wetland marked on aerial photograph).
General location: McPherson County, South Dakota (no USGS 7.5 min topographic map exists for the area).
Specific location: east side of Pond No. 1; transect runs 19.9 m on an azimuth of 290 deg from upper to lower end; permanent markers at meters 0.0 (lower end) and 19.9 (upper end).
Water regime: surface water column is 17 cm deep at meter 0.0 and 0 cm deep at meter 2.0 (exposed soil-standing water interface); salinity 2.5 ppt, specific conductivity 4300 μmhos, salinity class: moderately brackish.
Slope inclination along transect:

Transect segment, m	Slope, %
0-2.0	water
2.0-7.1	8
7.1-9.0	9
9.0-10.9	9
10.9-12.8	15
12.8-14.9	19
14.9-19.9	27

Disturbance: light grazing by cattle and buffalo.
Number of plant species recorded along transect: 49
Sampling date: 24 July 1979
Vegetation sampling methods: Belt transect quadrat size: 0.50 m^2; cover board every 0.5 m.

Transect identification number: 18
Watershed: Ordway Prairie Pond No. 2 (specific wetland marked on aerial photograph).
General location: McPherson County, South Dakota (no USGS 7.5 min topographic map exists for the area).
Specific location: northeast corner of Pond No.2; transect runs 24.7 m on an azimuth of 236 deg from upper to lower end; permanent markers at meters 0.0 (lower end) and 24.7 (upper end).
Water regime: no surface water.
Slope inclination along transect:

Transect segment, m	Slope, %
0-4.0	3
4.0-7.0	3
7.0-11.3	3
11.3-13.5	6
13.5-15.9	11
15.9-18.0	14
18.0-20.5	16
20.5-23.6	16
23.6-24.7	11

Disturbance: light grazing by cattle and buffalo.
Number of plant species recorded along transect: 50
Sampling date: 24 July 1979
Vegetation sampling methods: Belt transect quadrat size: 0.50 m^2; cover board every 0.50 m.

Transect identification number: 19
Watershed: Ordway Prairie Pond No. 3 (specific wetland marked on aerial photograph).
General location: McPherson County, South Dakota (no USGS 7.5 min topographic map exists for the area).
Specific location: north side of Pond No. 3; transect runs 13.4 m on an azimuth of 164 deg from upper to lower end; permanent markers at meters 0.0 (lower end) and 13.4 (upper end).
Water regime: no surface water.
Slope inclination along transect:

Transect segment, m	Slope, %
0-3.0	4
3.0-6.0	7
6.0-8.7	14
8.7-12.5	14
12.5-13.4	11

Disturbance: light grazing by cattle and buffalo.
Number of plant species recorded along transect: 30
Sampling date: 25 July 1979
Vegetation sampling methods: Belt transect quadrat size: 0.50 m^2; cover board every 0.5 m.

Transect identification number: 20
Watershed: Ordway Prairie Pond No. 3 (specific wetland marked on aerial photograph).
General location: McPherson County, South Dakota (no USGS 7.5 min topographic map exists for the area).
Specific location: northeast corner of Pond No. 3; transect runs 16.5 m on an azimuth of 235 deg from upper to lower end; permanent markers at meters 0.0 (lower end) and 16.5 (upper end).
Water regime: no surface water.
Slope inclination along transect:

Transect segment, m	Slope, %
0-4.0	4
4.0-6.0	5
6.0-11.3	9
11.3-14.0	7
14.0-16.5	9

Disturbance: light grazing by cattle and buffalo.
Number of plant species recorded along transect: 36
Sampling date: 25 July 1979
Vegetation sampling methods: Belt transect quadrat size: 0.50 m^2; cover board every 0.50 m.

APPENDIX B: DIRECT GRADIENT ANALYSIS GRAPHS FOR TRANSECTS 1-20

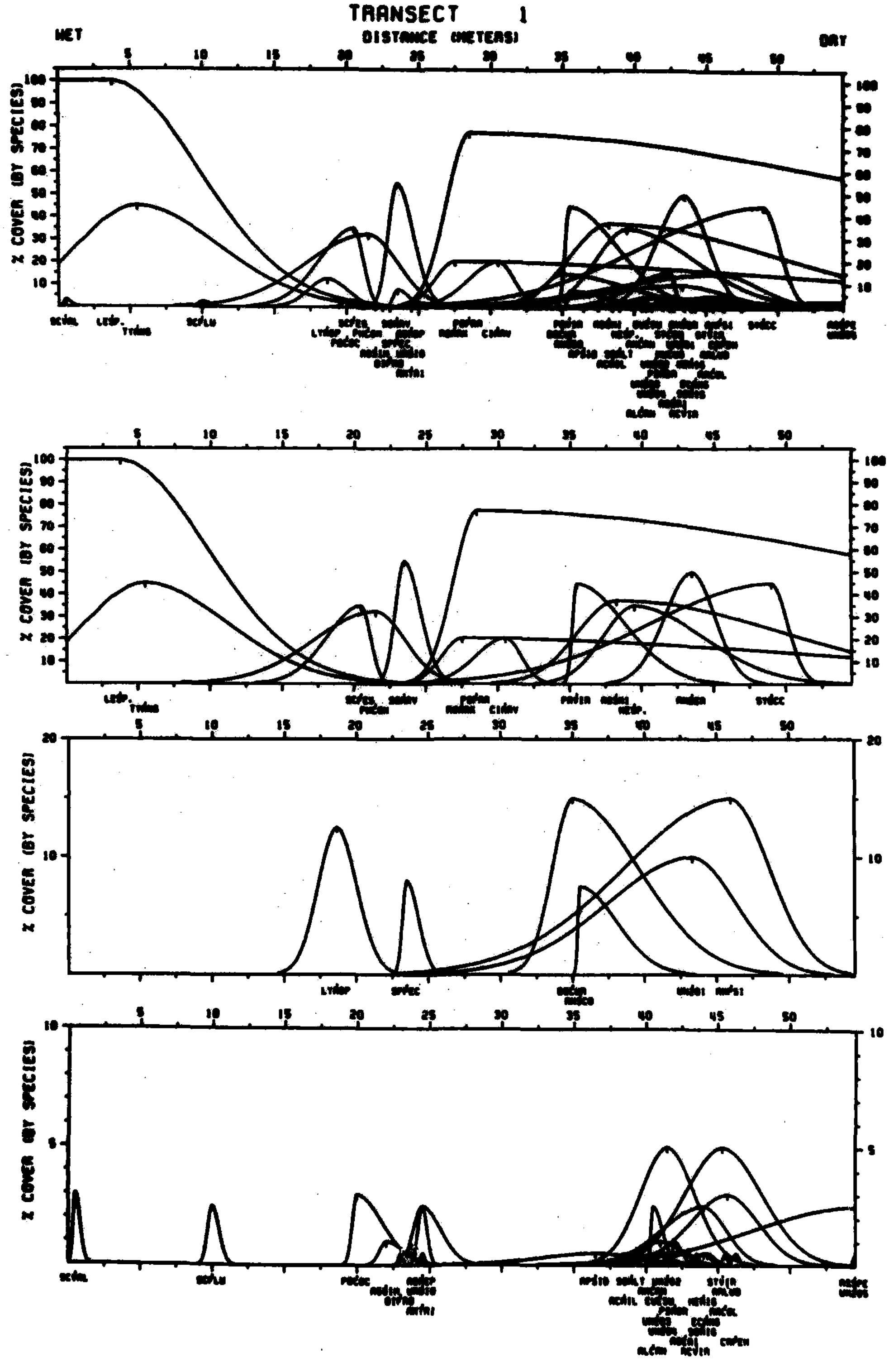


Figure B1. Direct gradient analysis graph, transect 01 (Continued)

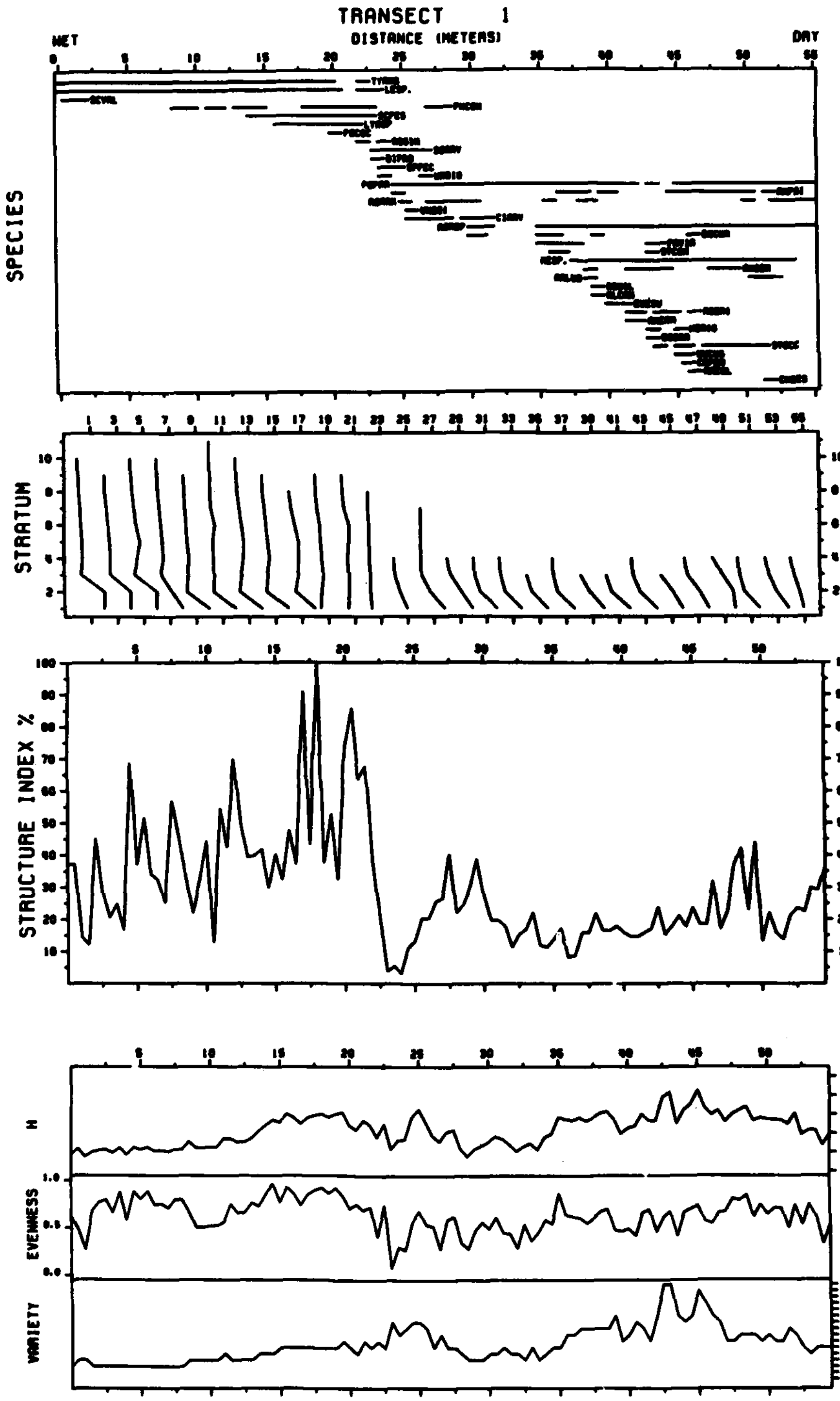


Figure B1. (Concluded)

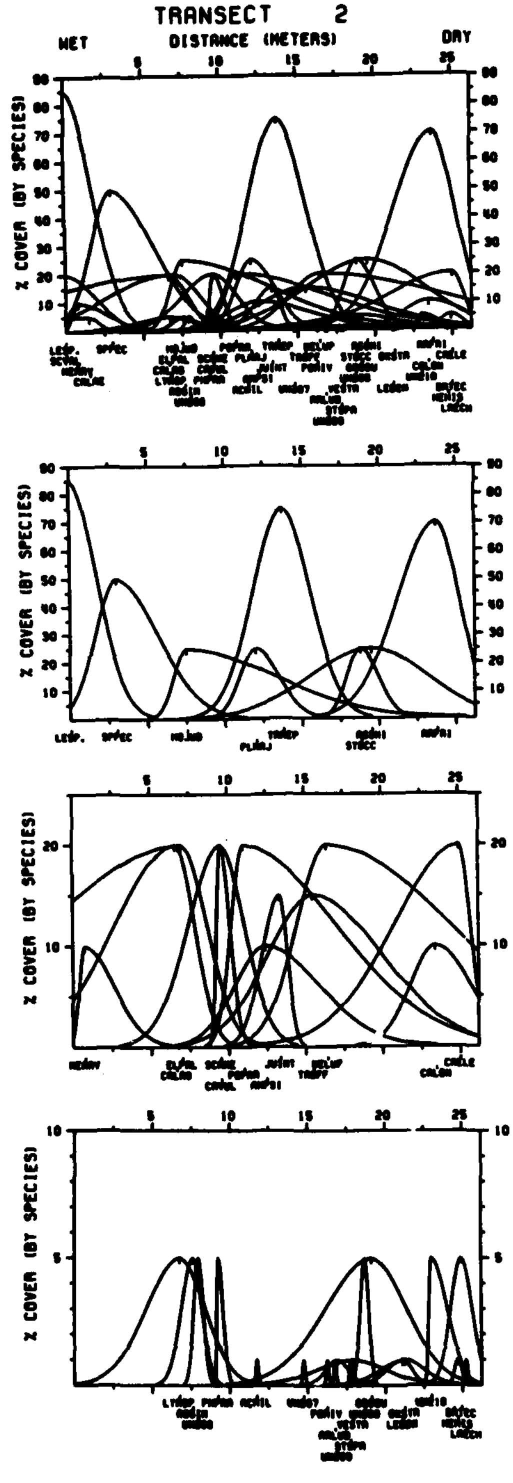


Figure B2. Direct gradient analysis graph, transect 02 (Continued)

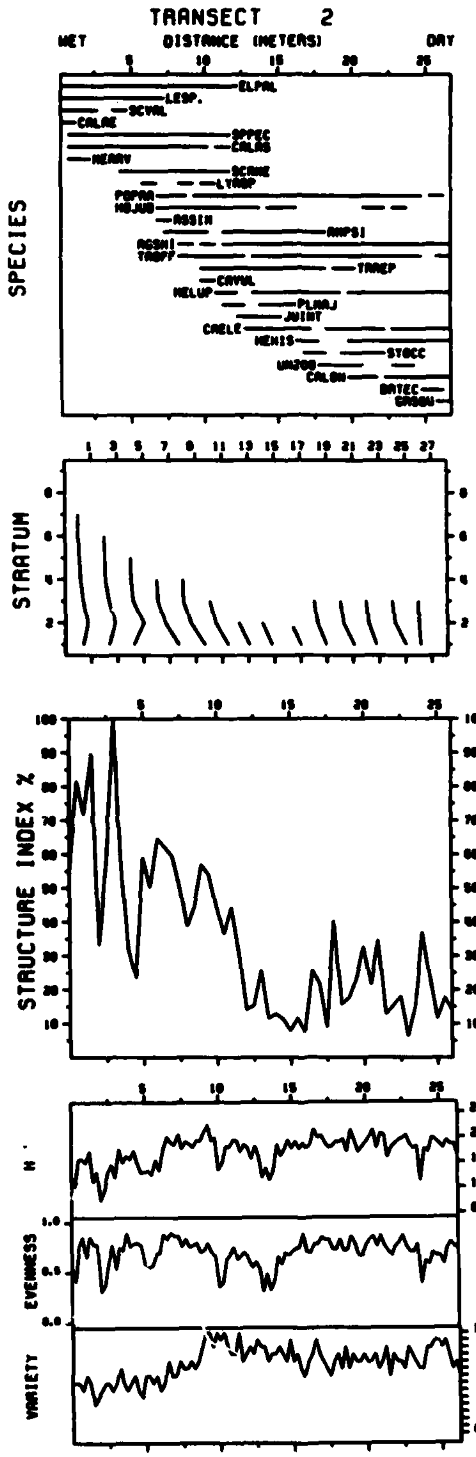


Figure B2. (Concluded)

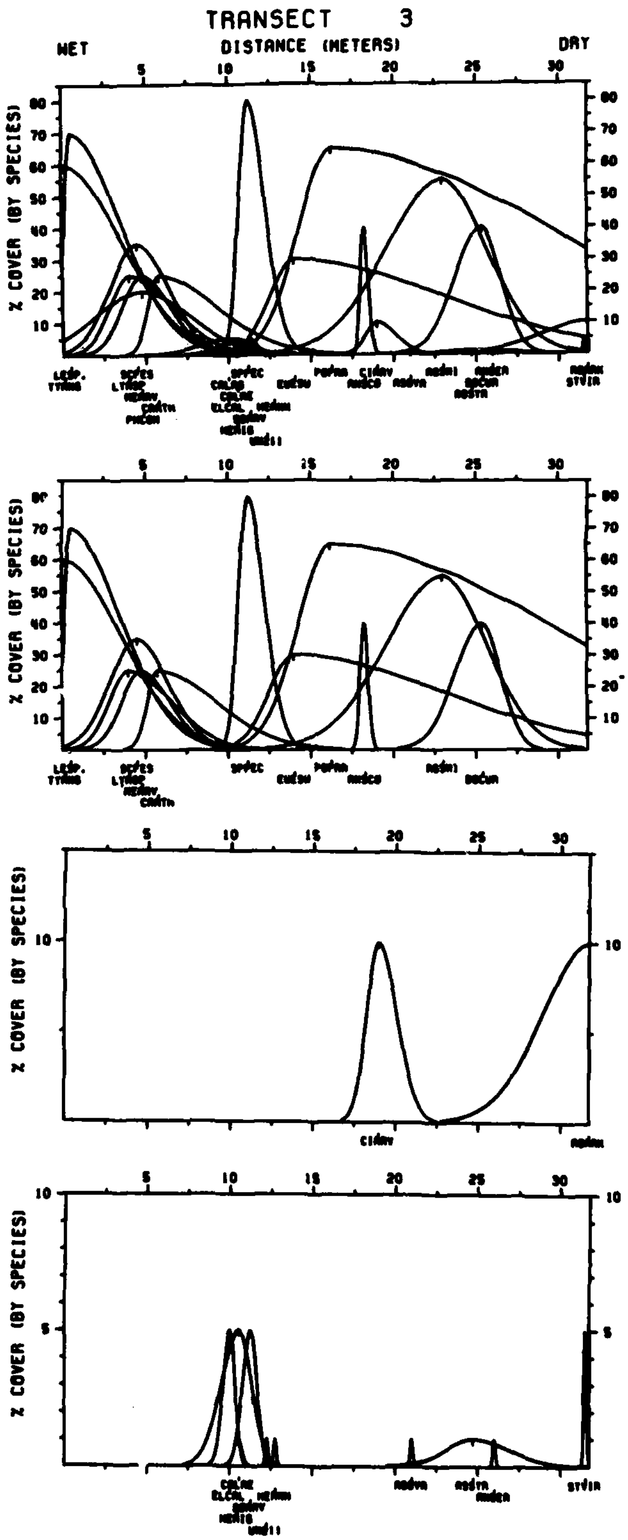
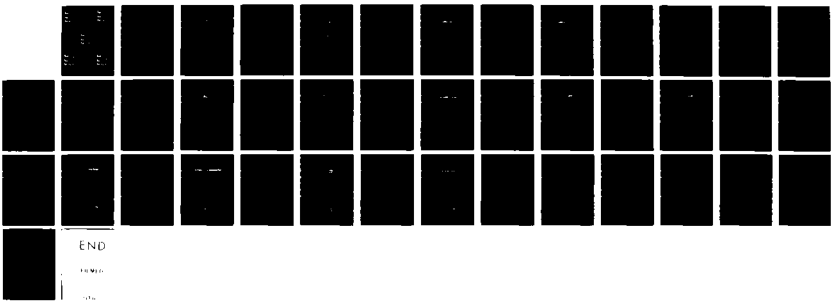


Figure B3. Direct gradient analysis graph, transect 03 (Continued)

AD-A120 798 USE OF VEGETATION IN DELINEATING WETLAND BORDERS IN UPPER MISSOURI RIVER..(U) VIRGINIA POLYTECHNIC INST AND STATE UNIV BLACKSBURG W C JOHNSON ET AL. AUG 82 2/2

UNCLASSIFIED WES-TR/Y-82-1 DACW39-78-C-0098 F/G 8/6 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

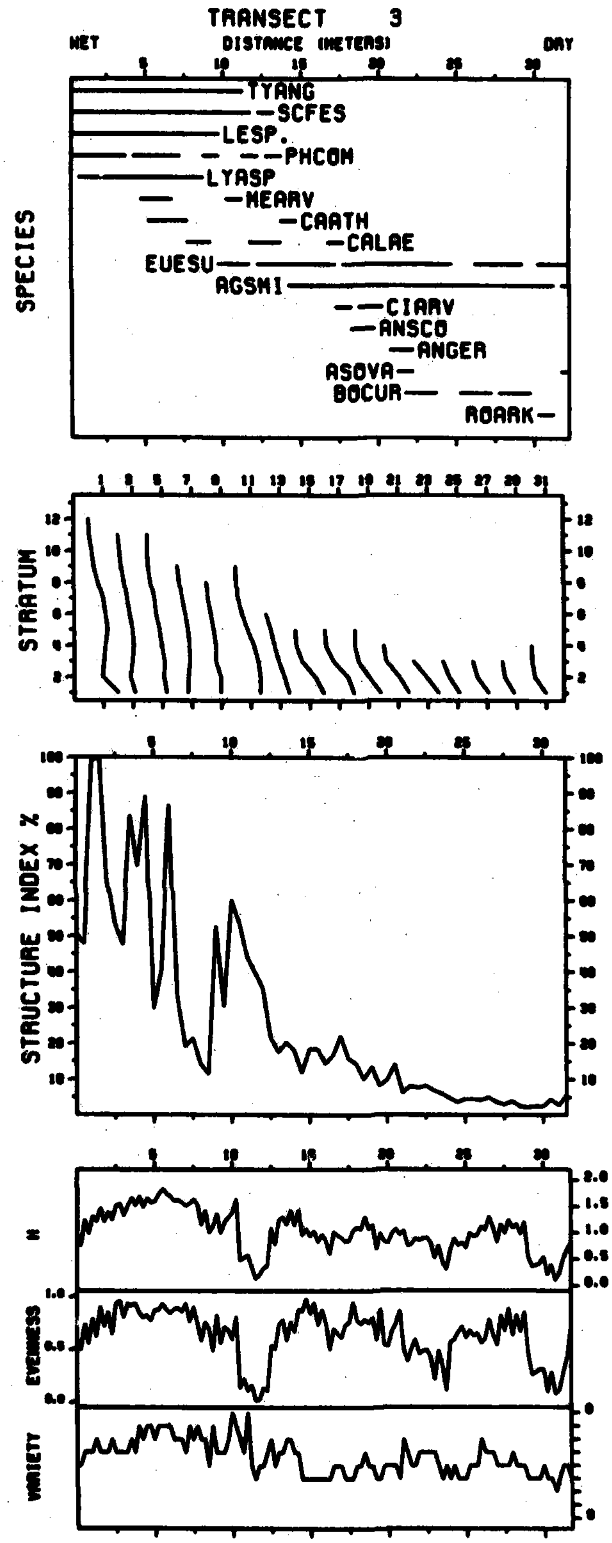


Figure B3. (Concluded)

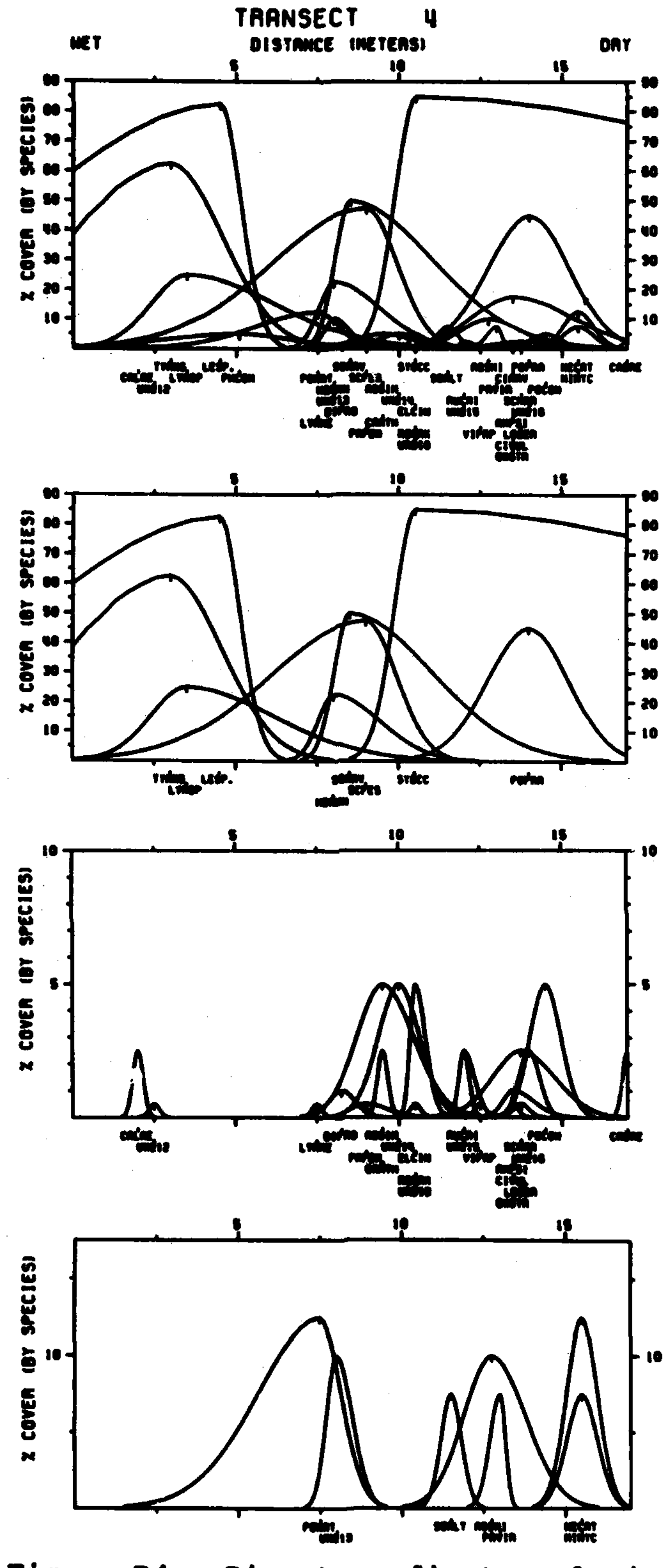


Figure B4. Direct gradient analysis graph, transect 04 (Continued)

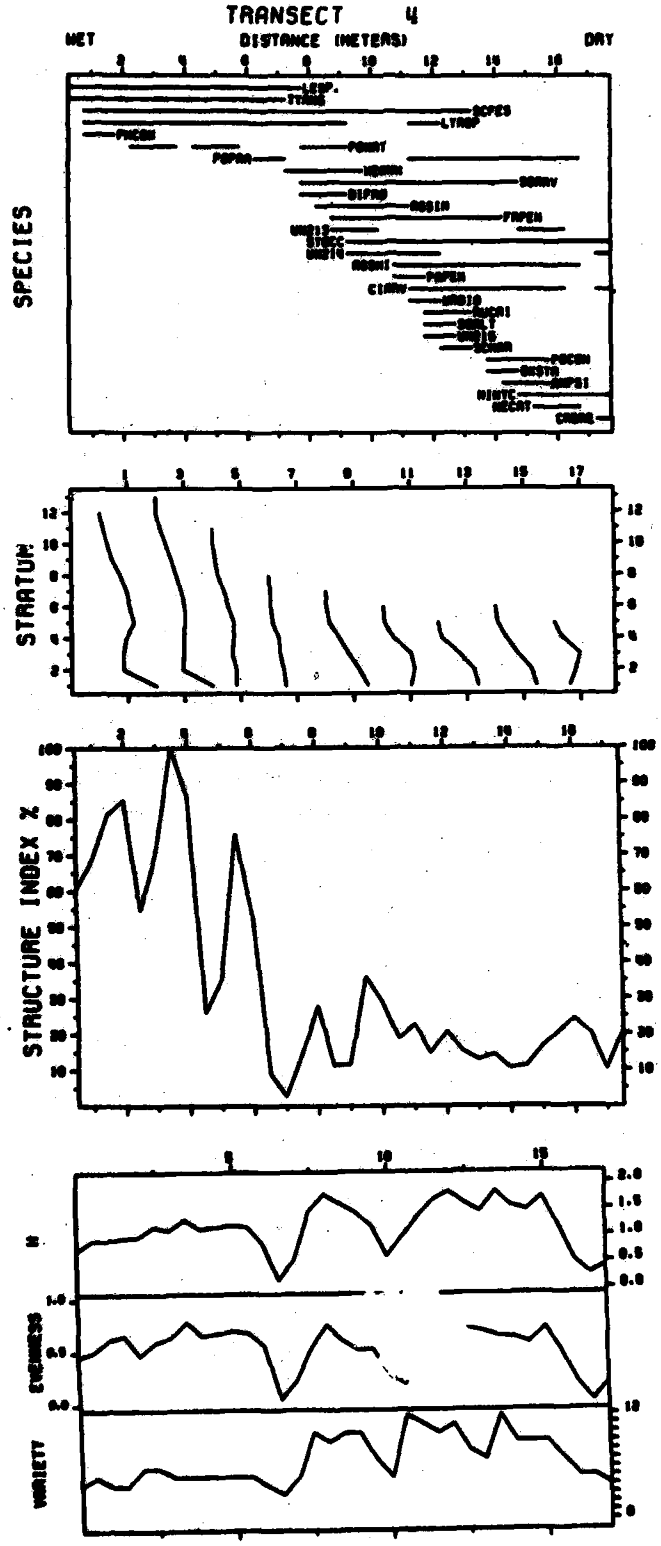


Figure B4. (Concluded)

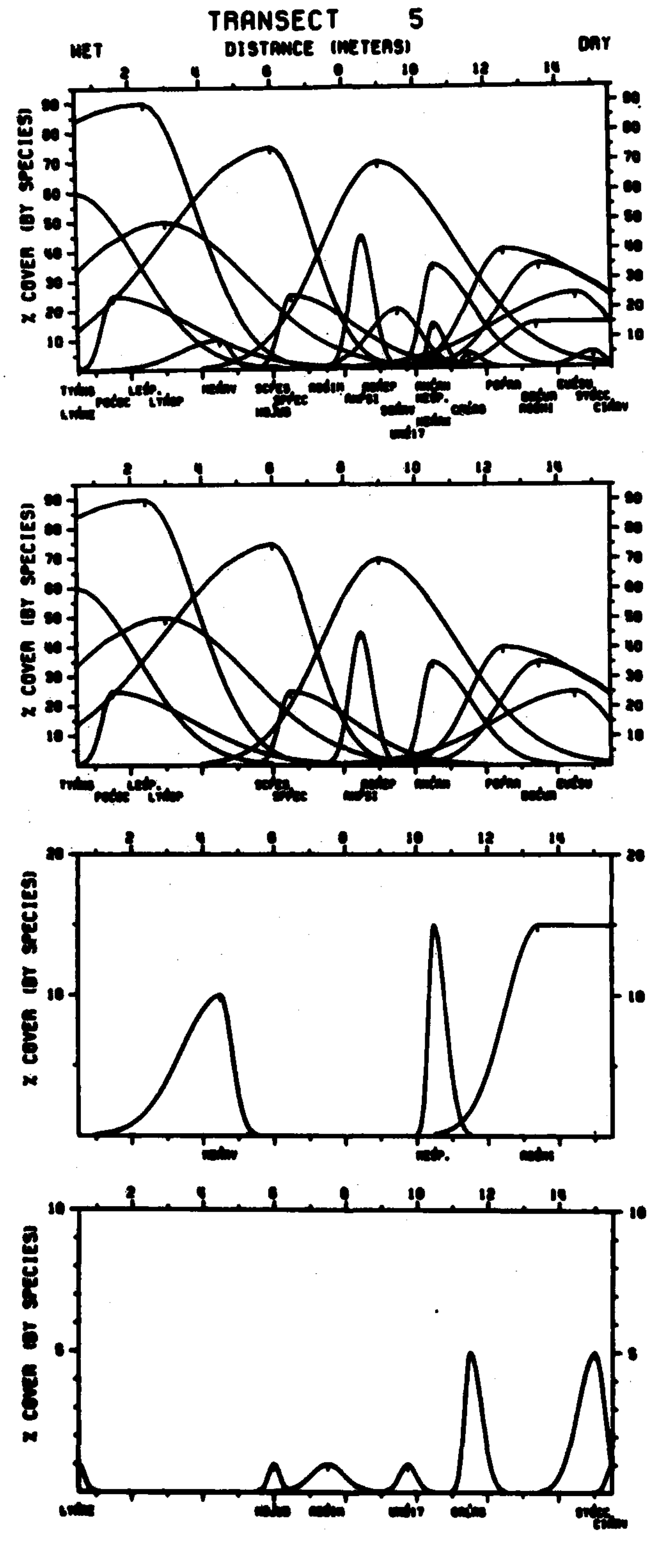


Figure B5. Direct gradient analysis graph, transect 05 (Continued)

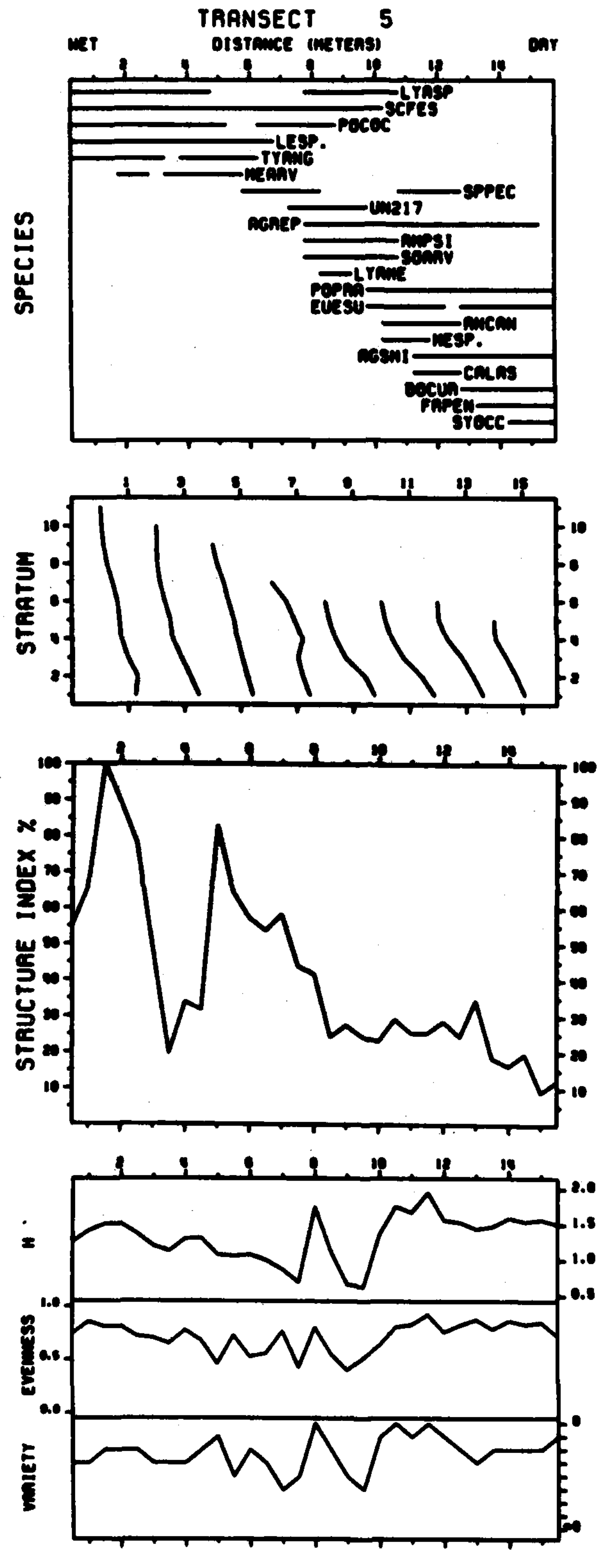


Figure B5. (Concluded)

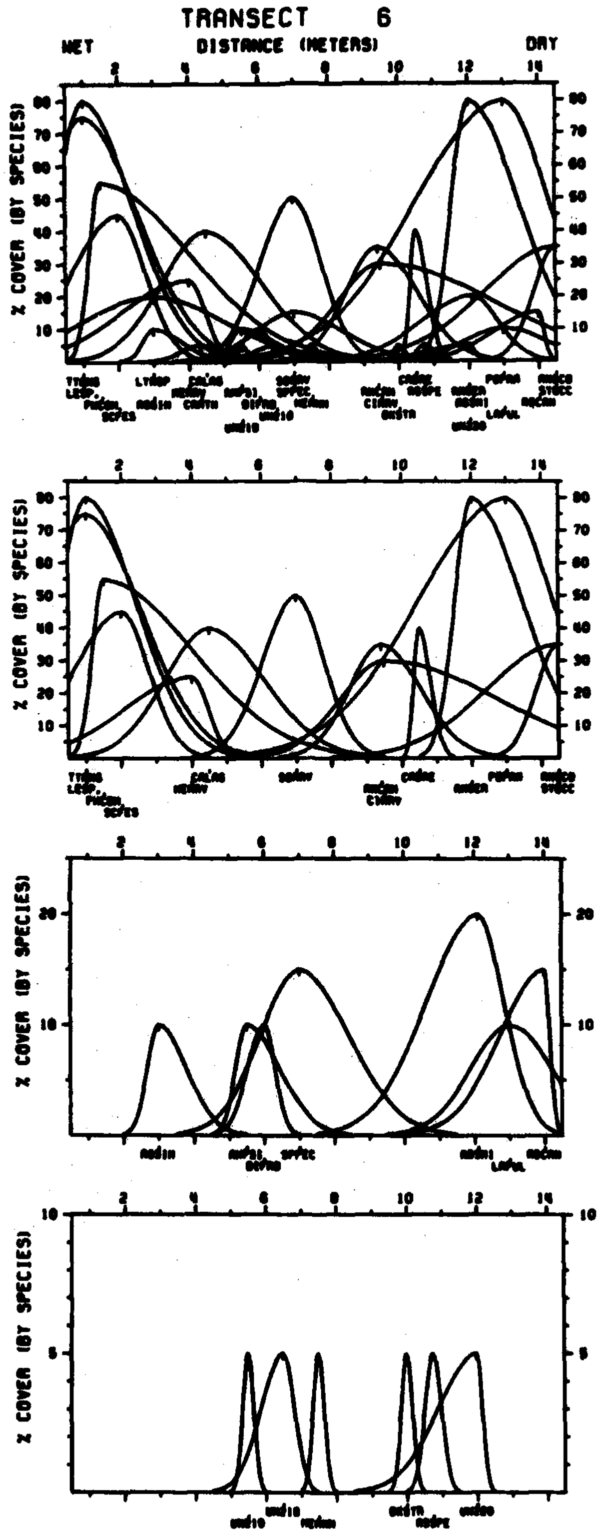


Figure B6. Direct gradient analysis graph, transect 06 (Continued)

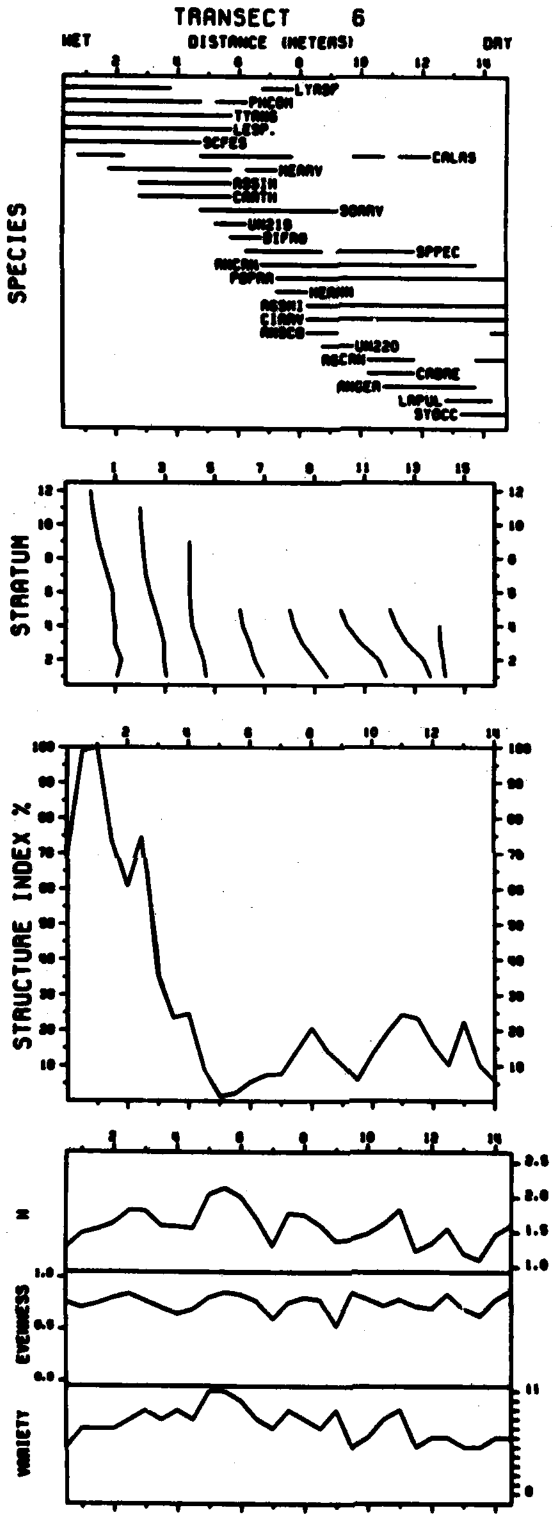


Figure B6. (Concluded)

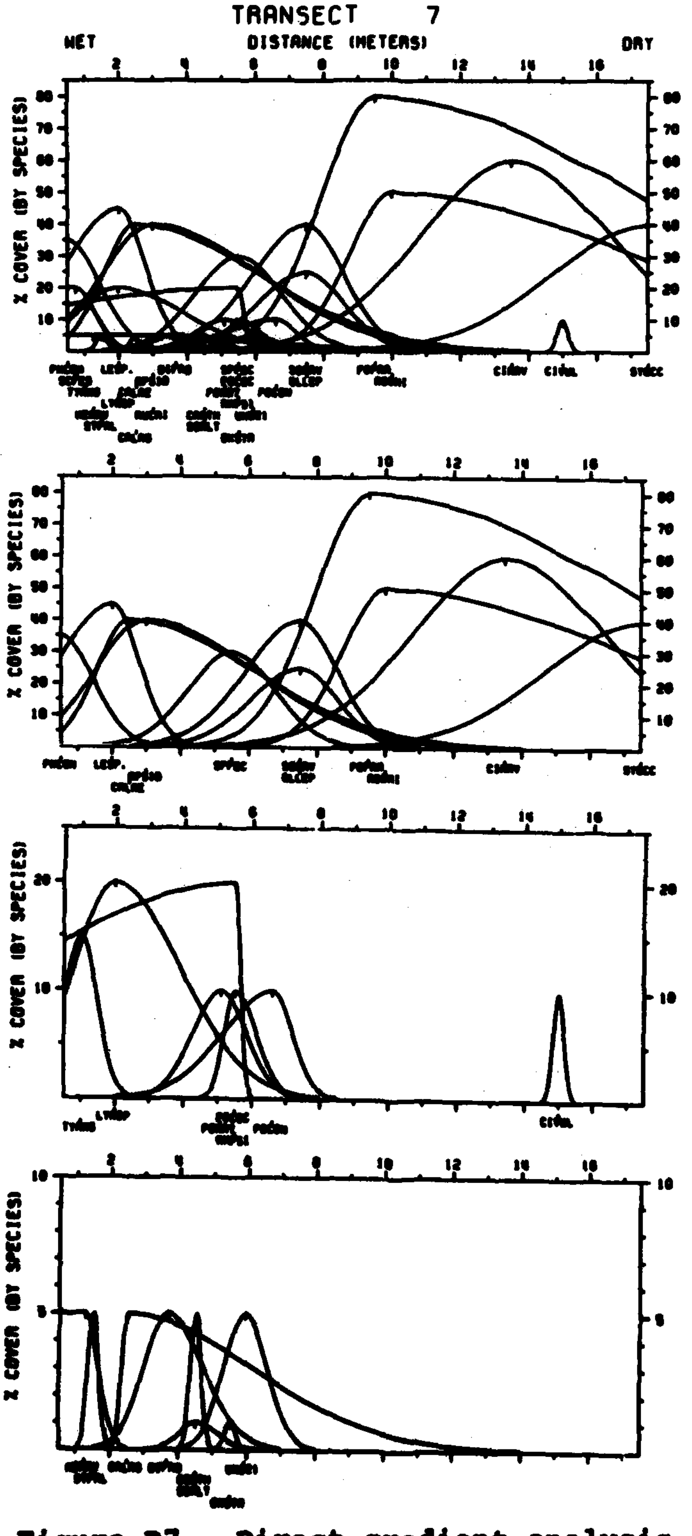


Figure B7. Direct gradient analysis graph, transect 07 (Continued)

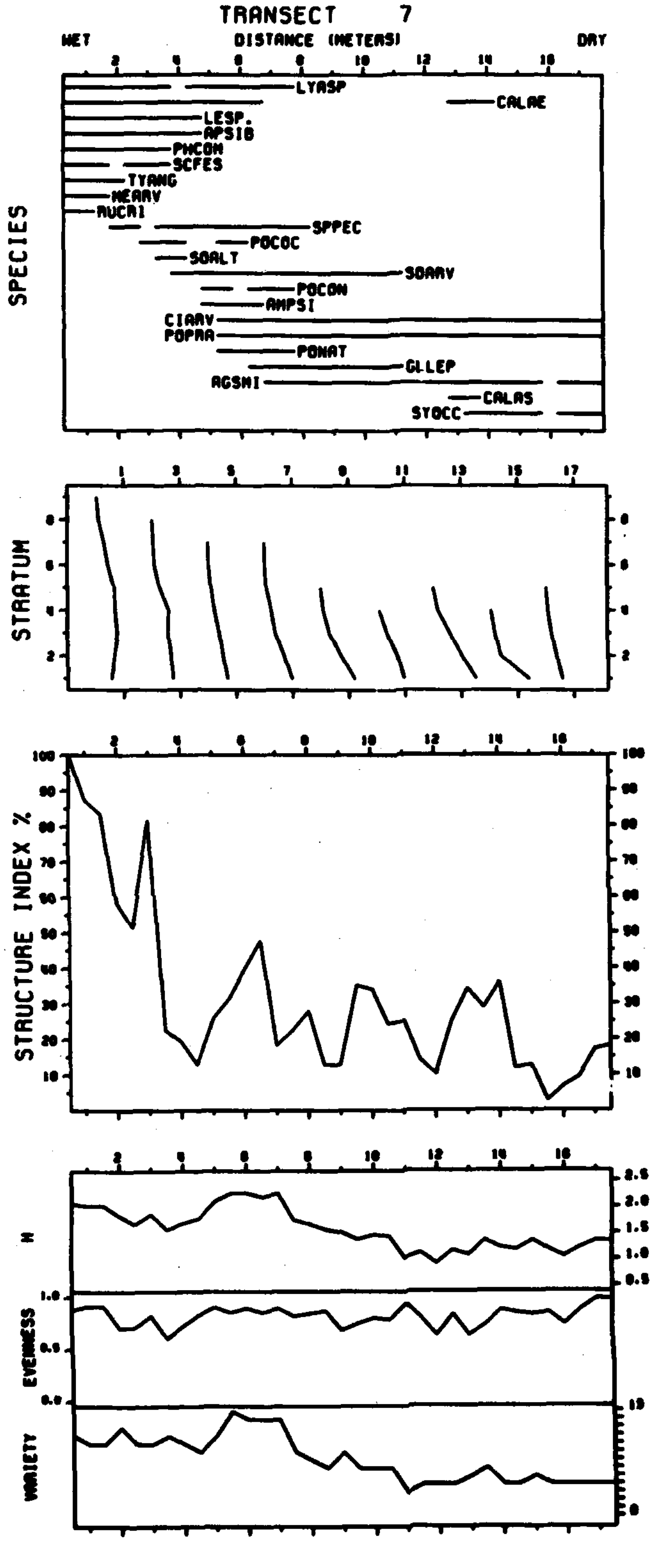


Figure B7. (Concluded)

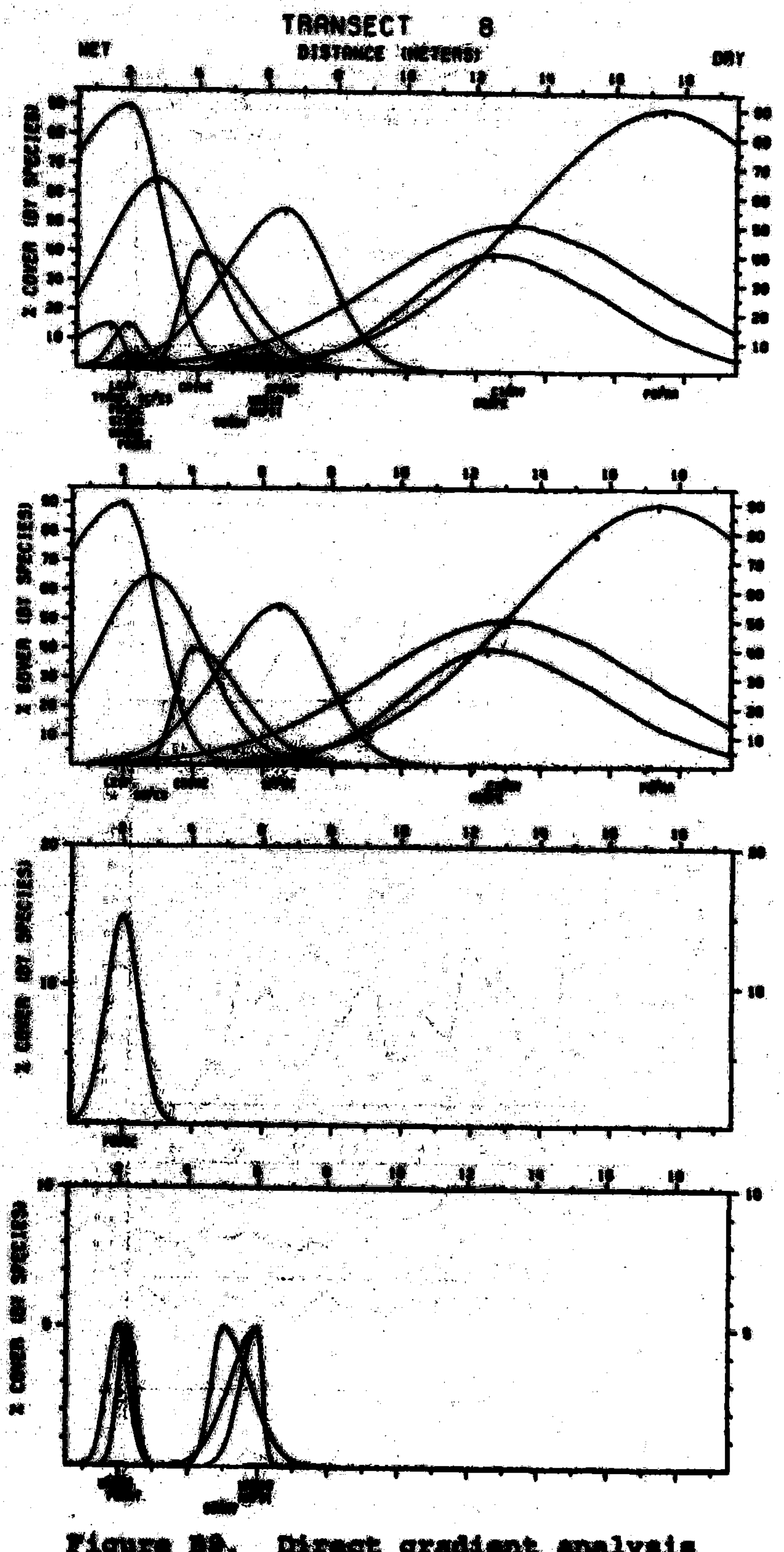


Figure B8. Direct gradient analysis graph, transect 08 (Continued)

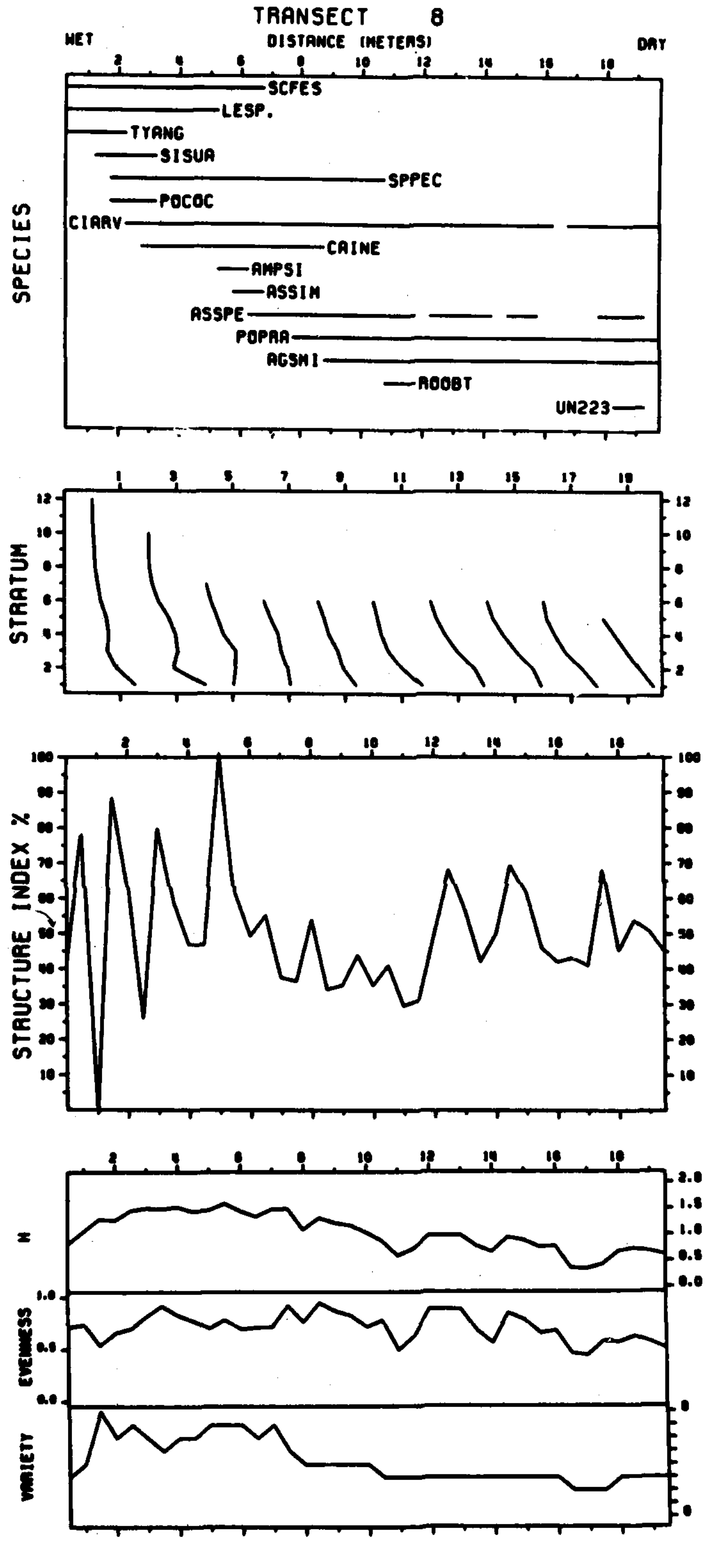


Figure B8. (Concluded)

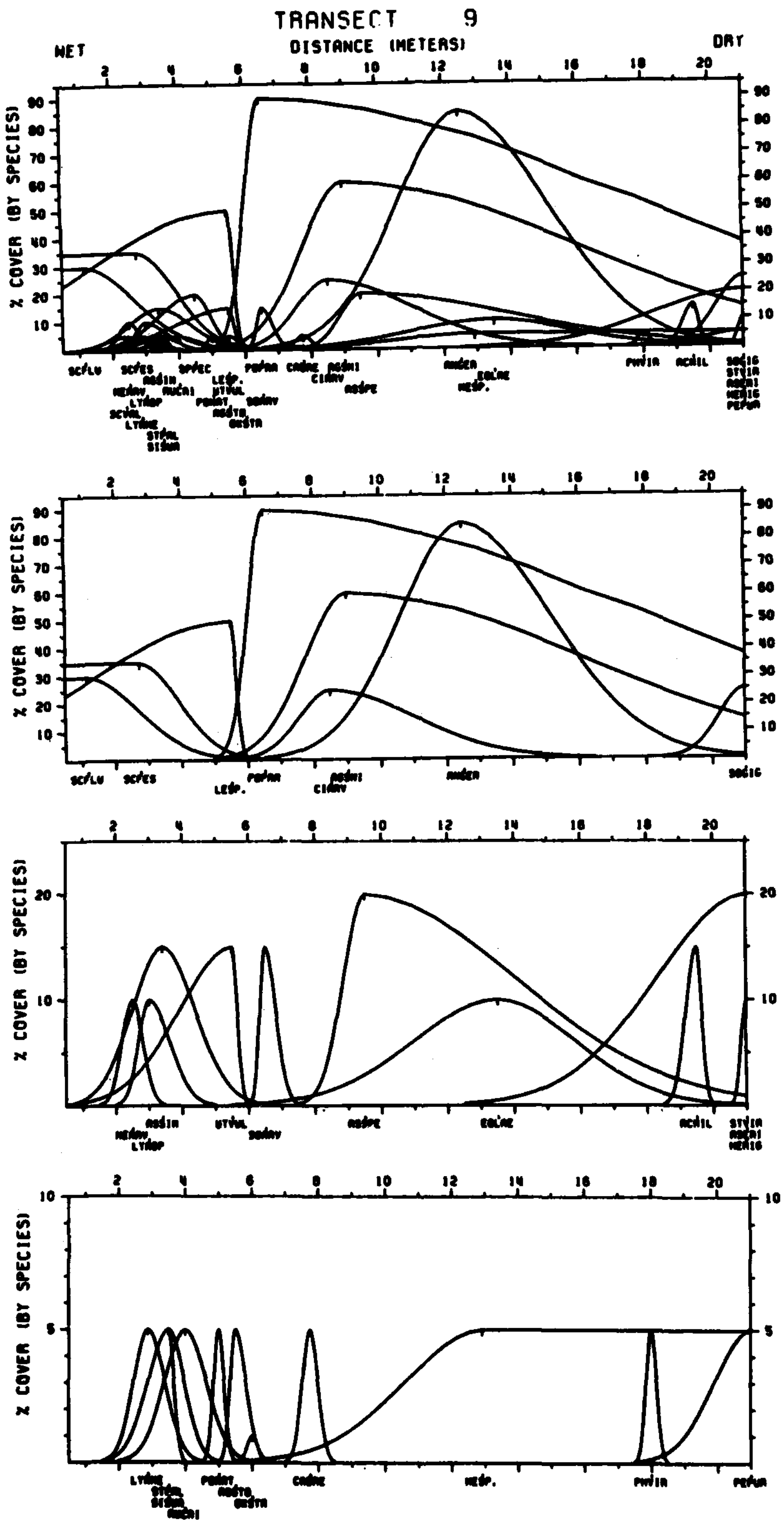


Figure B9. Direct gradient analysis graph, transect 09 (Continued)

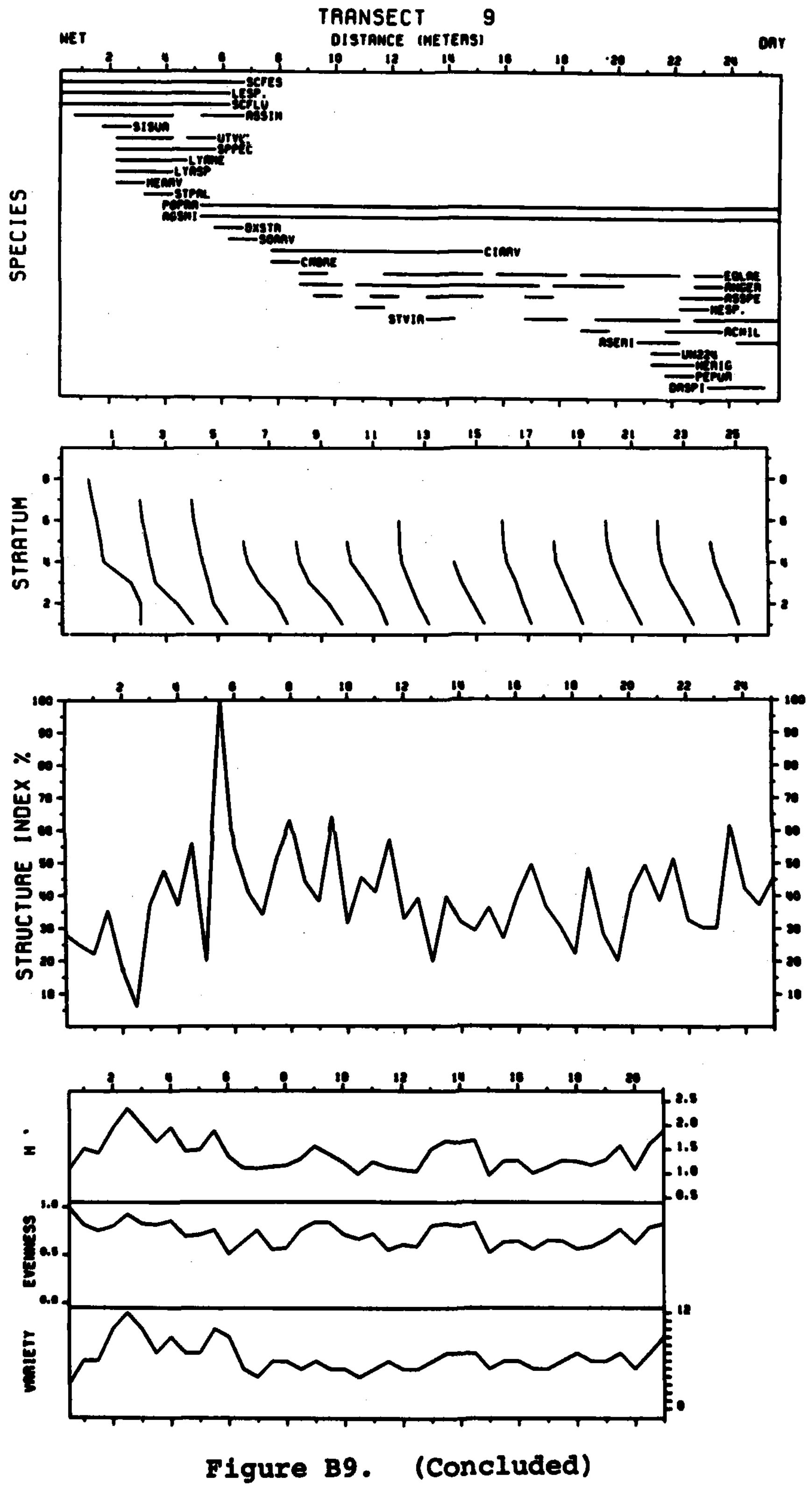


Figure B9. (Concluded)

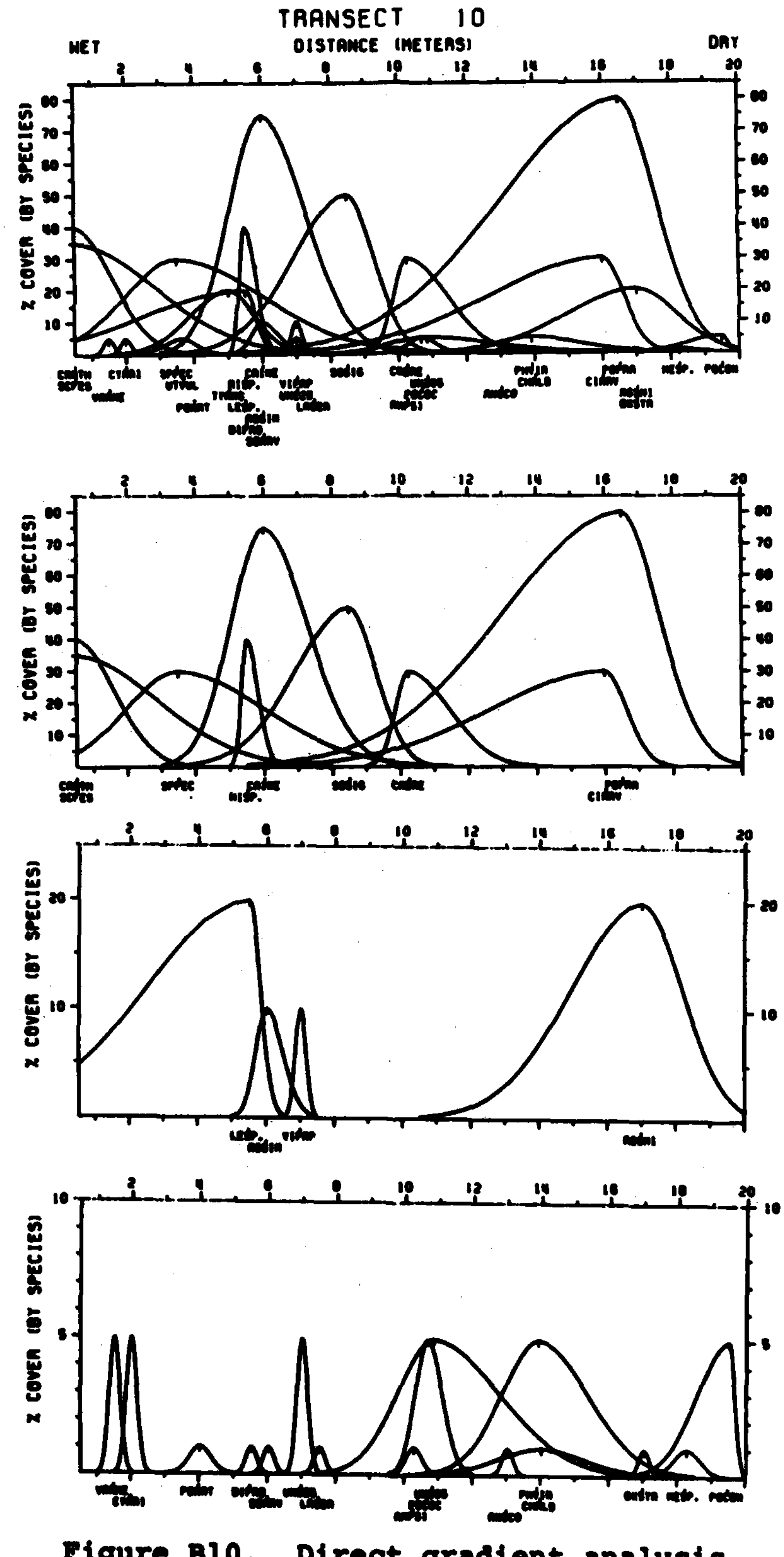


Figure B10. Direct gradient analysis graph, transect 10 (Continued)

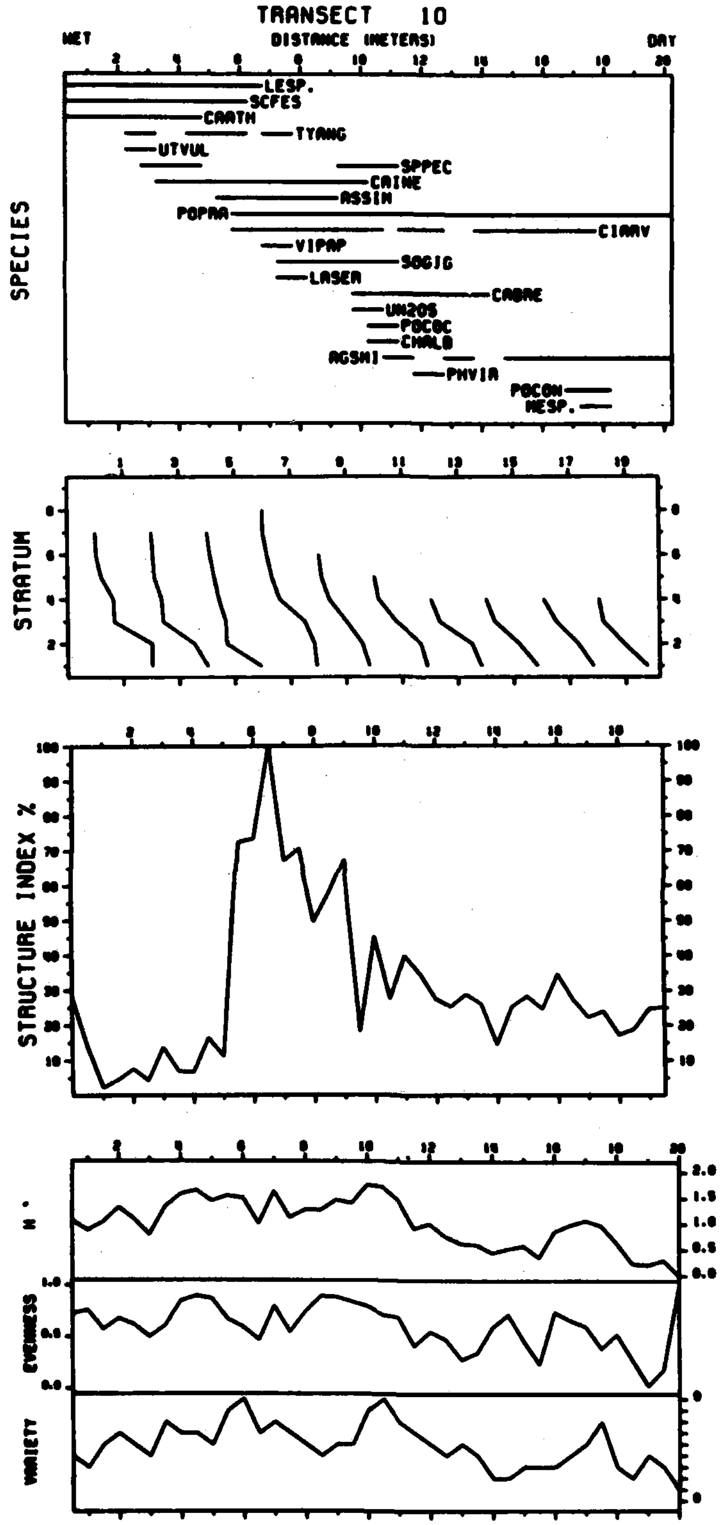


Figure B10. (Concluded)

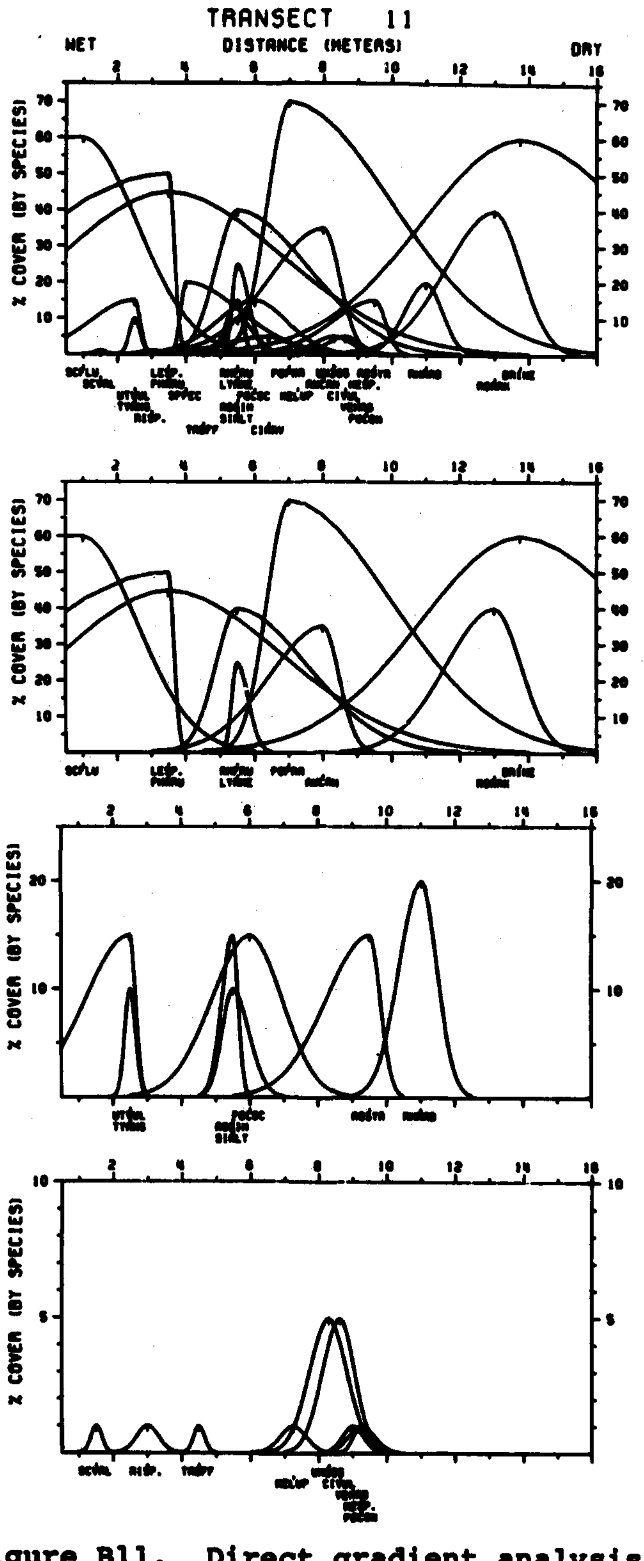


Figure B11. Direct gradient analysis graph, transect 11 (Continued)

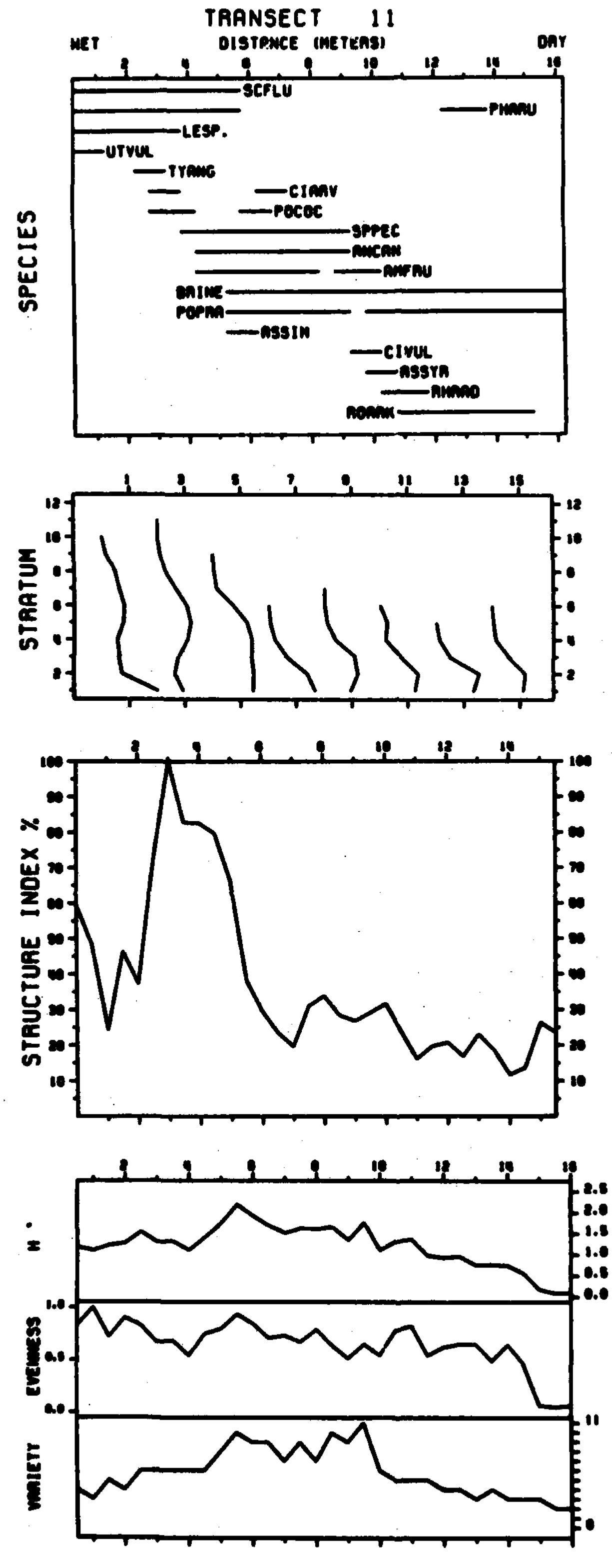


Figure B11. (Concluded)

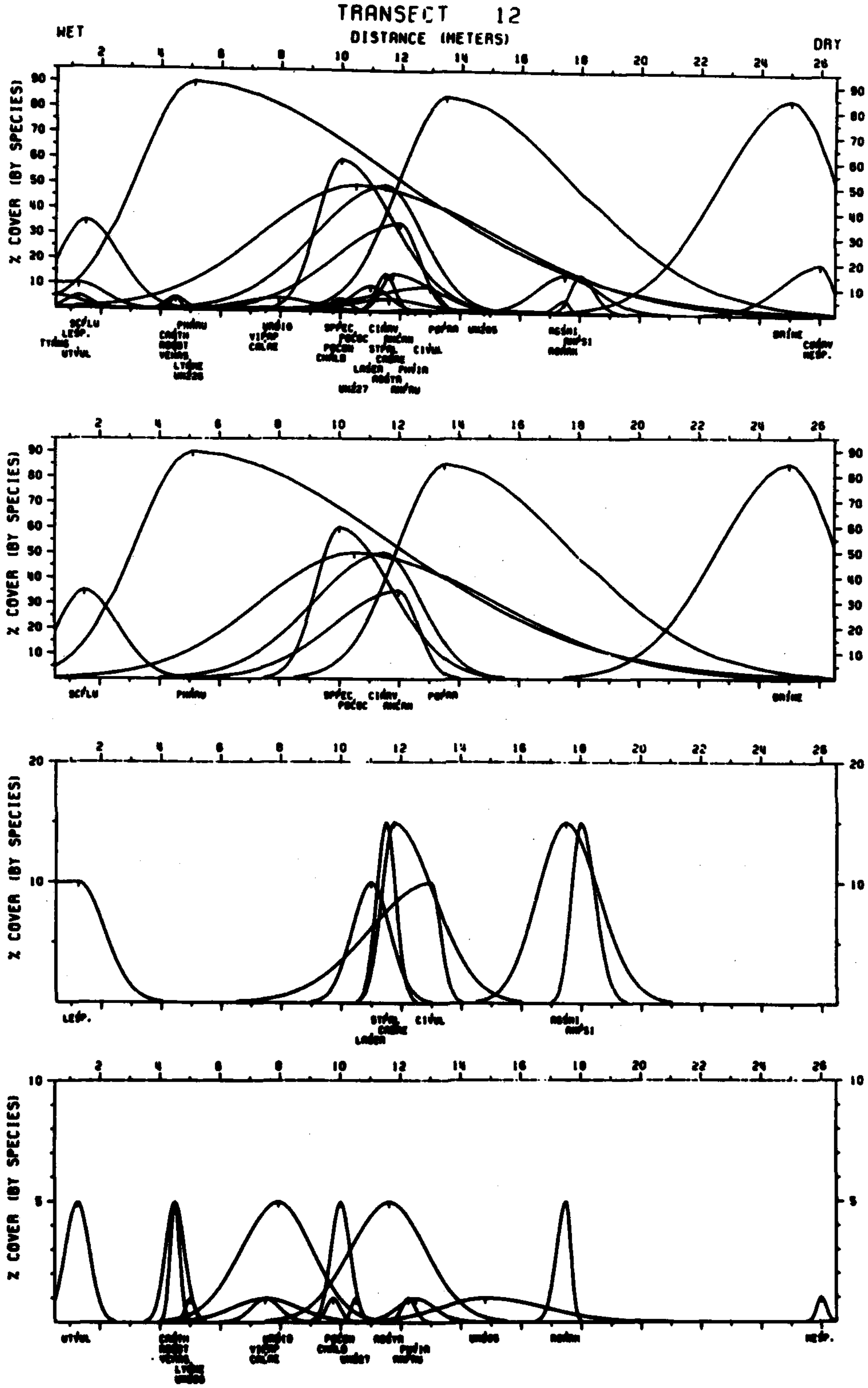


Figure B12. Direct gradient analysis graph, transect 12 (Continued)

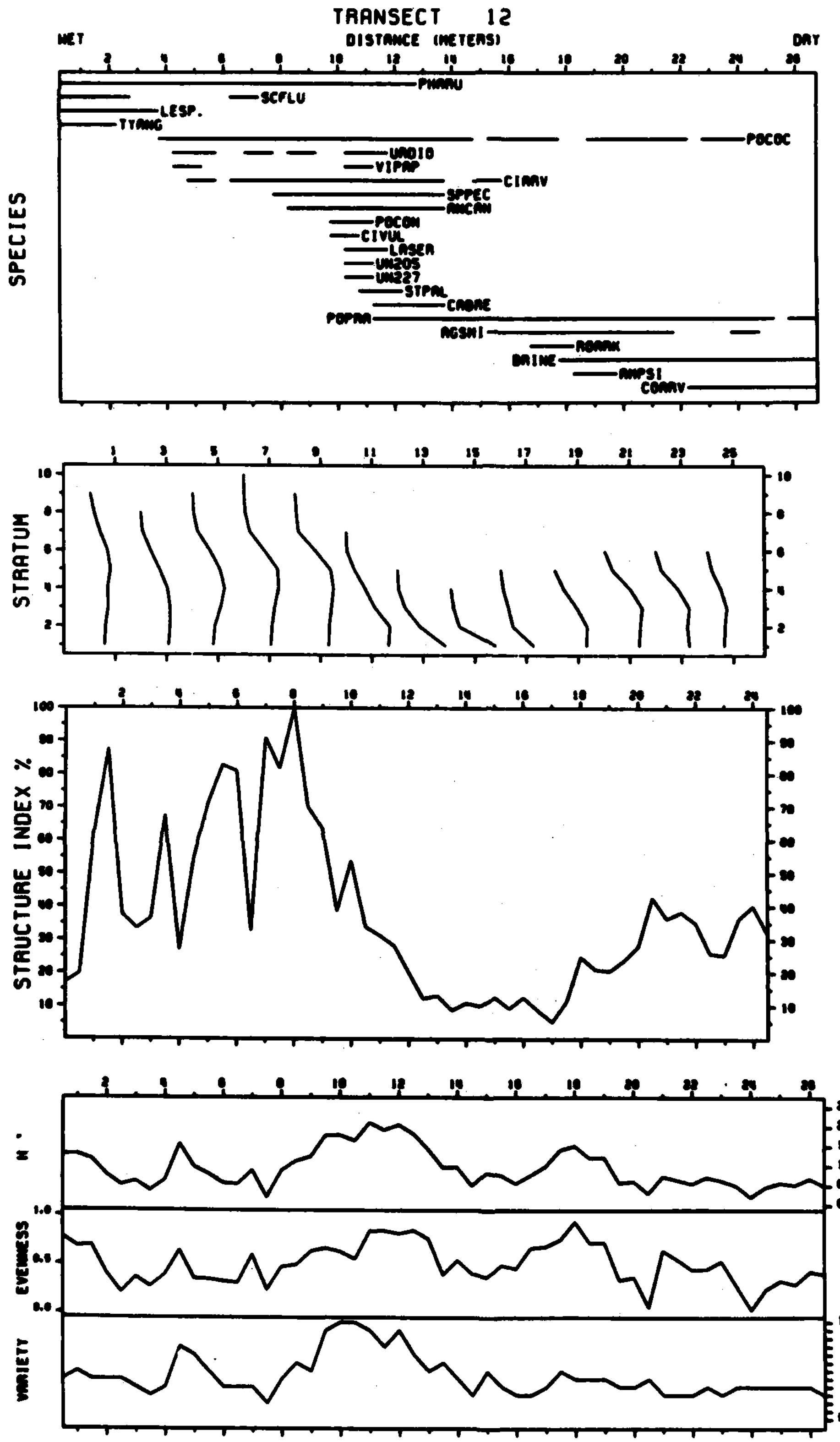


Figure B12. (Concluded)

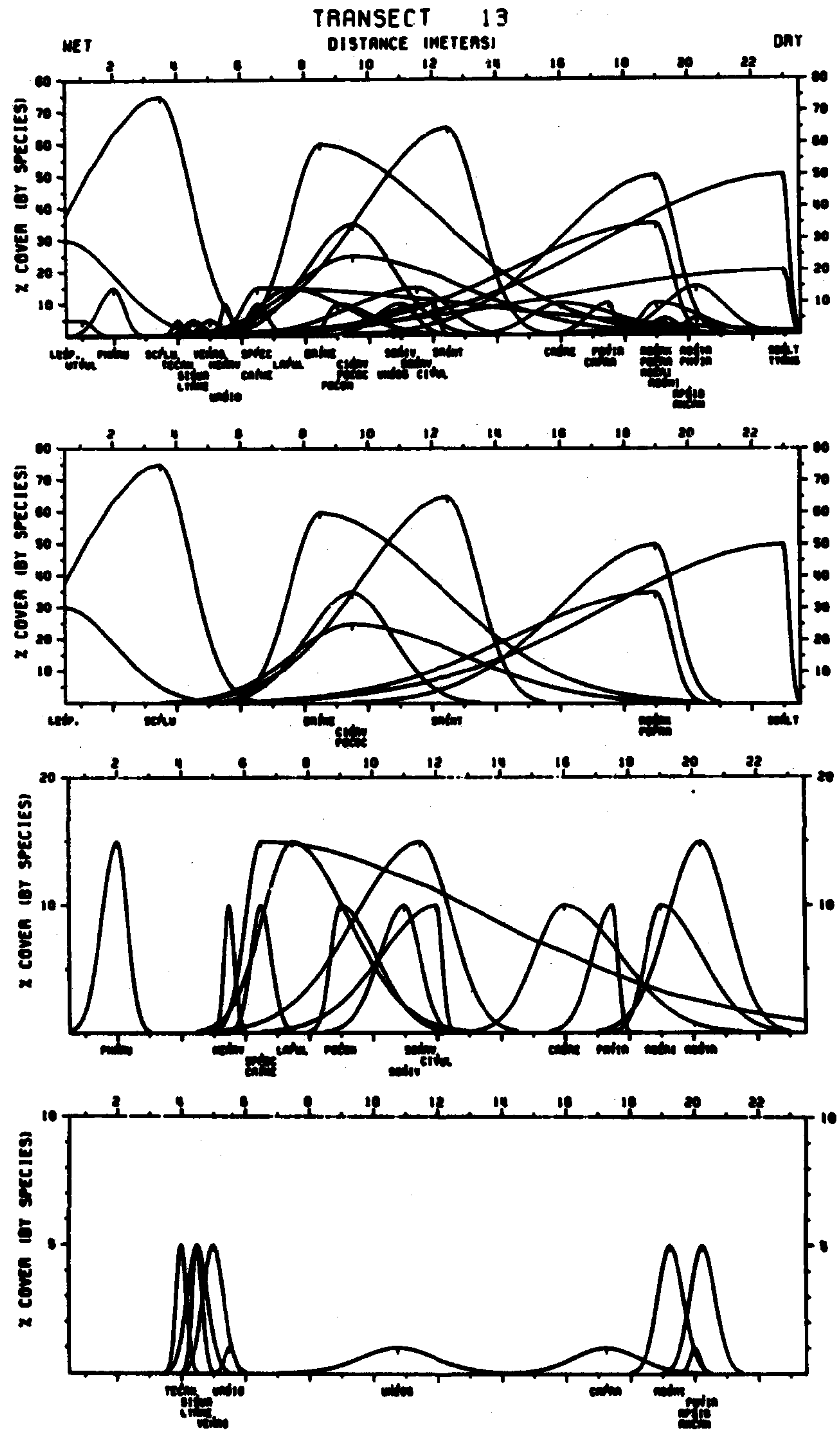


Figure B13. Direct gradient analysis graph, transect 13 (Continued)

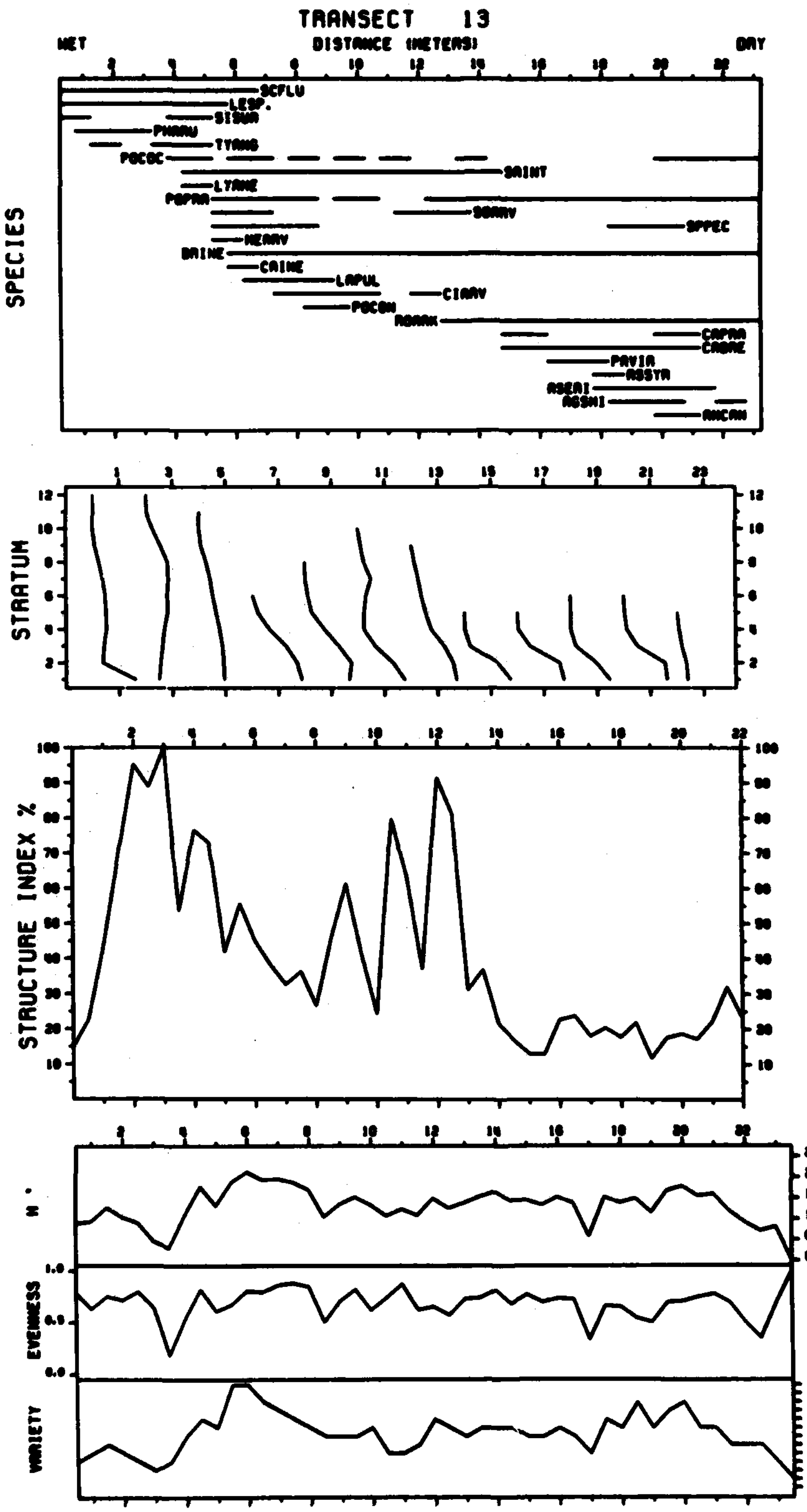


Figure B13. (Concluded)

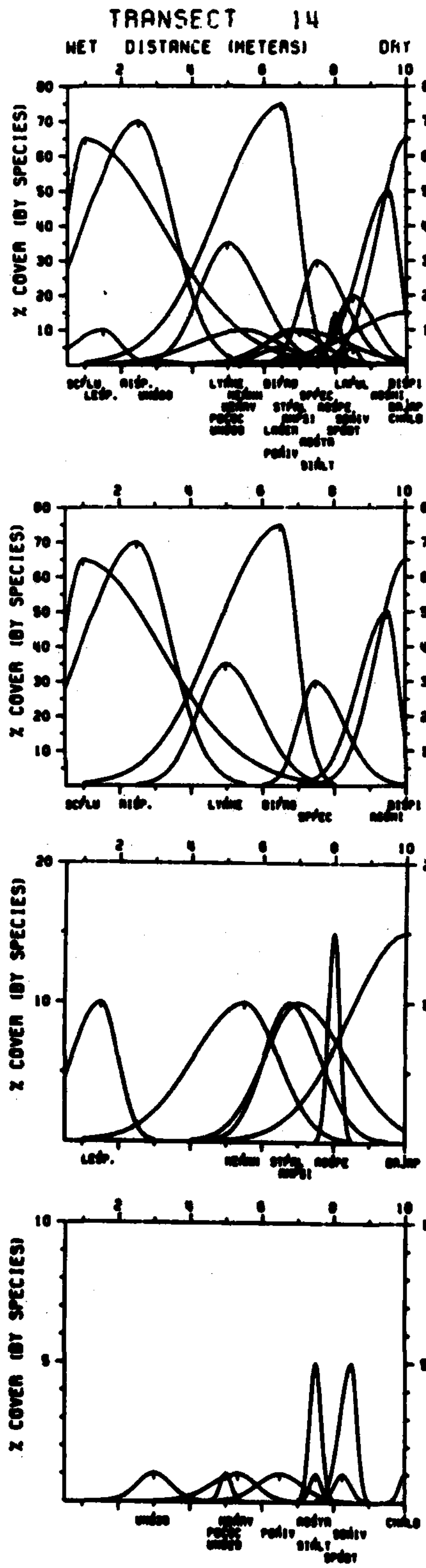


Figure B14. Direct gradient analysis graph, transect 14 (Continued)

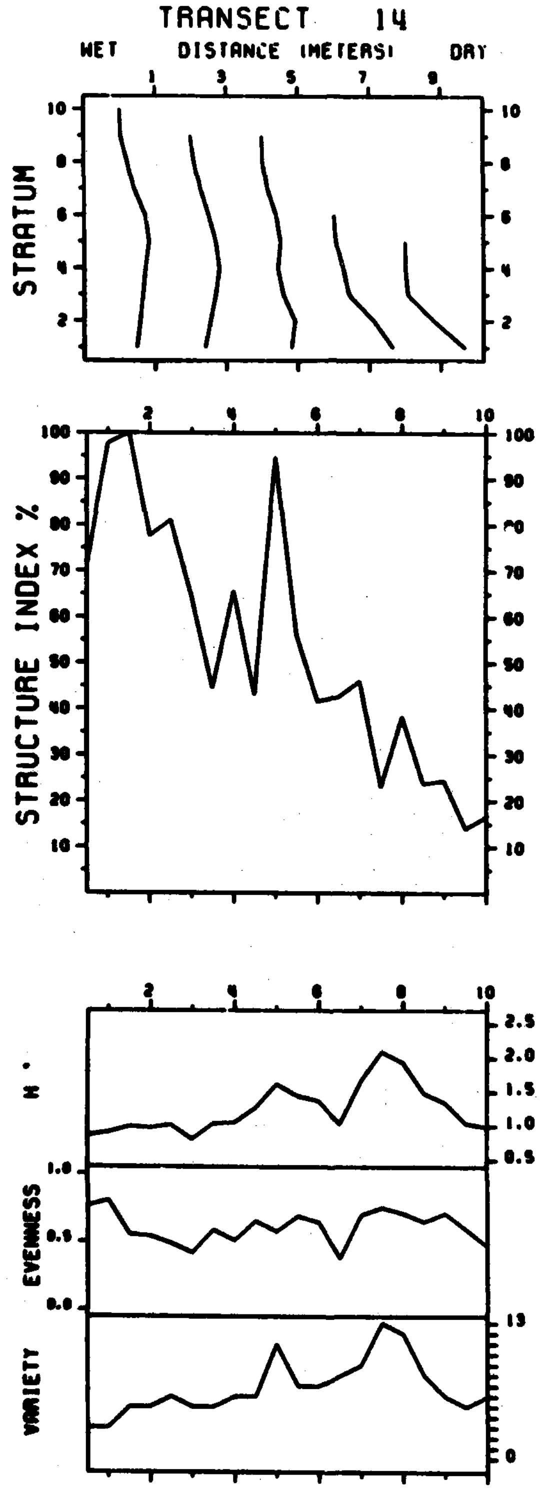


Figure B14. (Concluded)

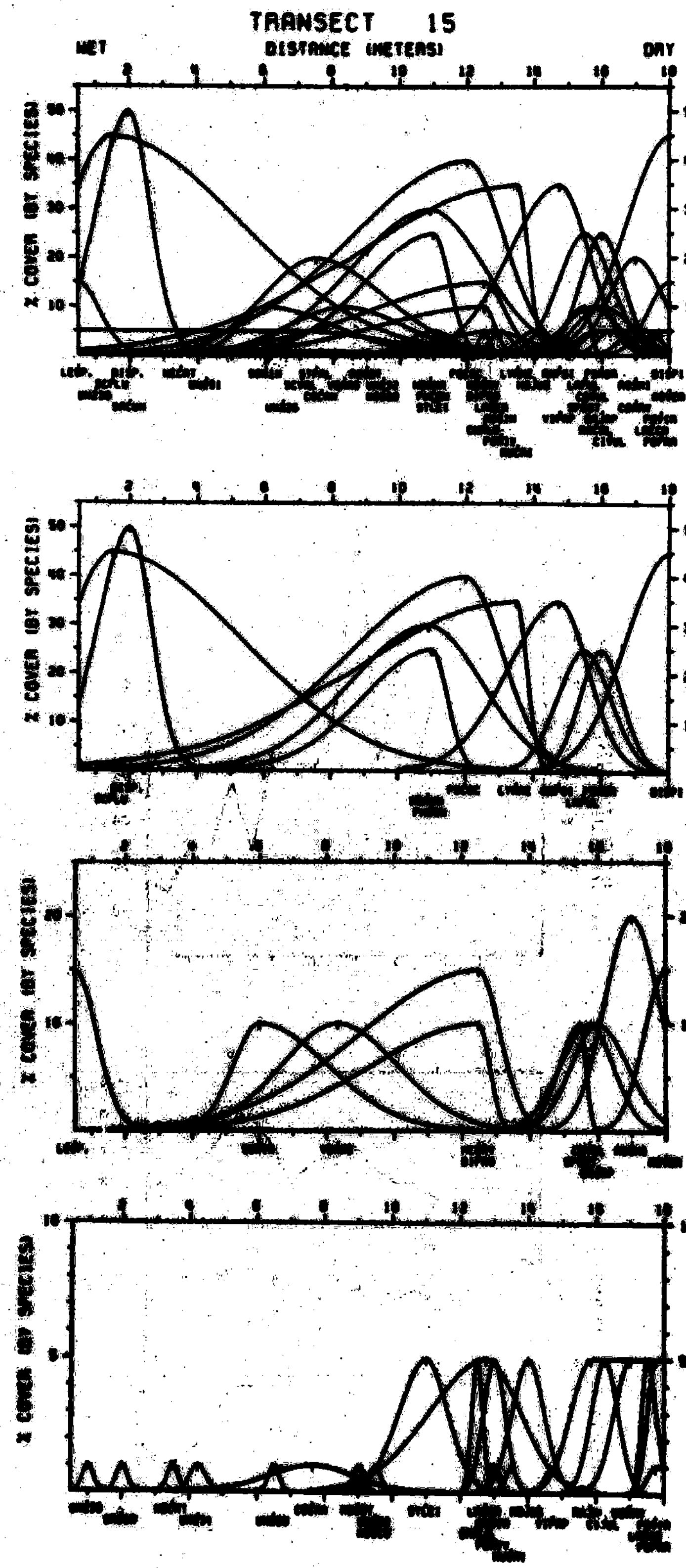


Figure B15. Direct gradient analysis graph, transect 15 (Continued)

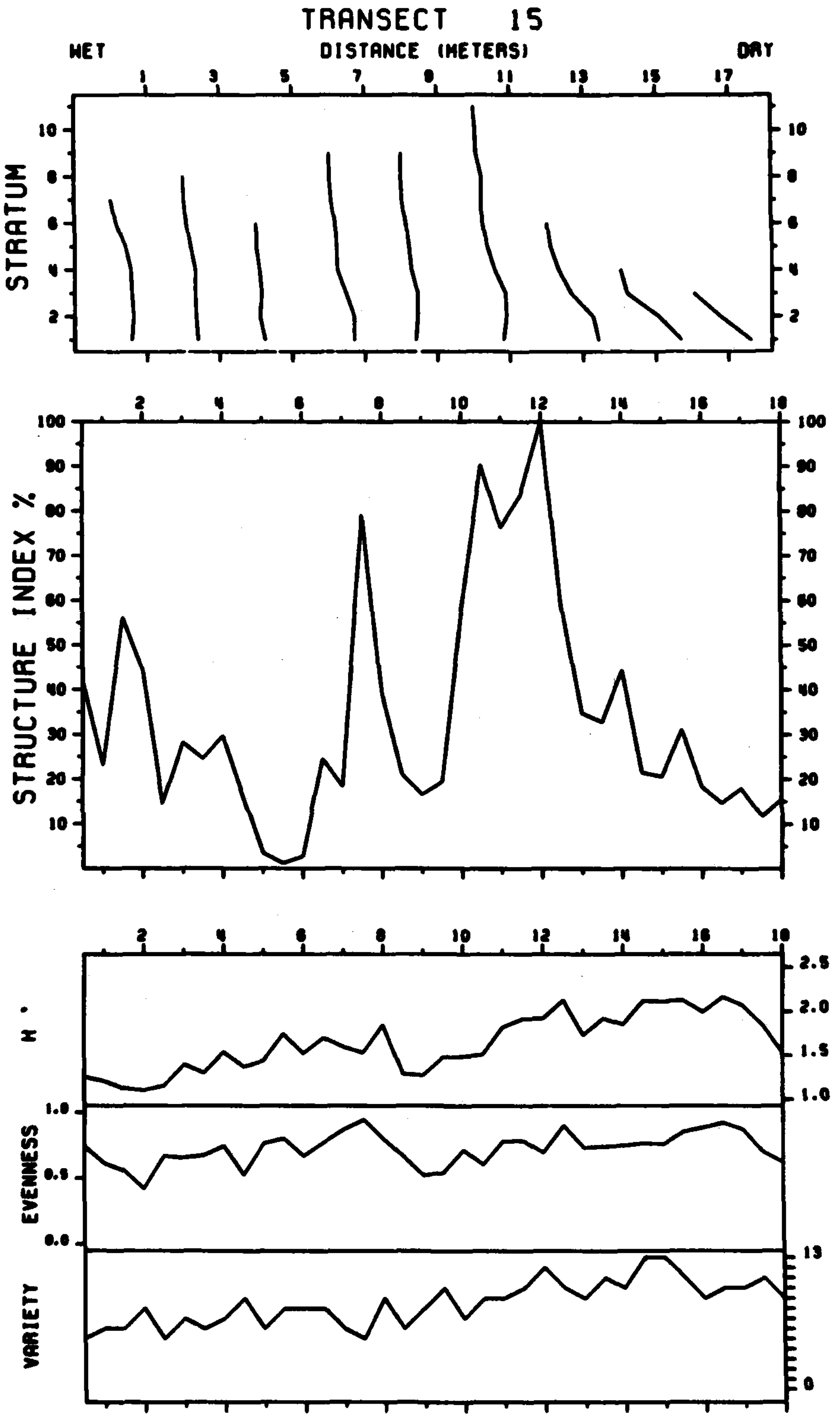


Figure B15. (Concluded)

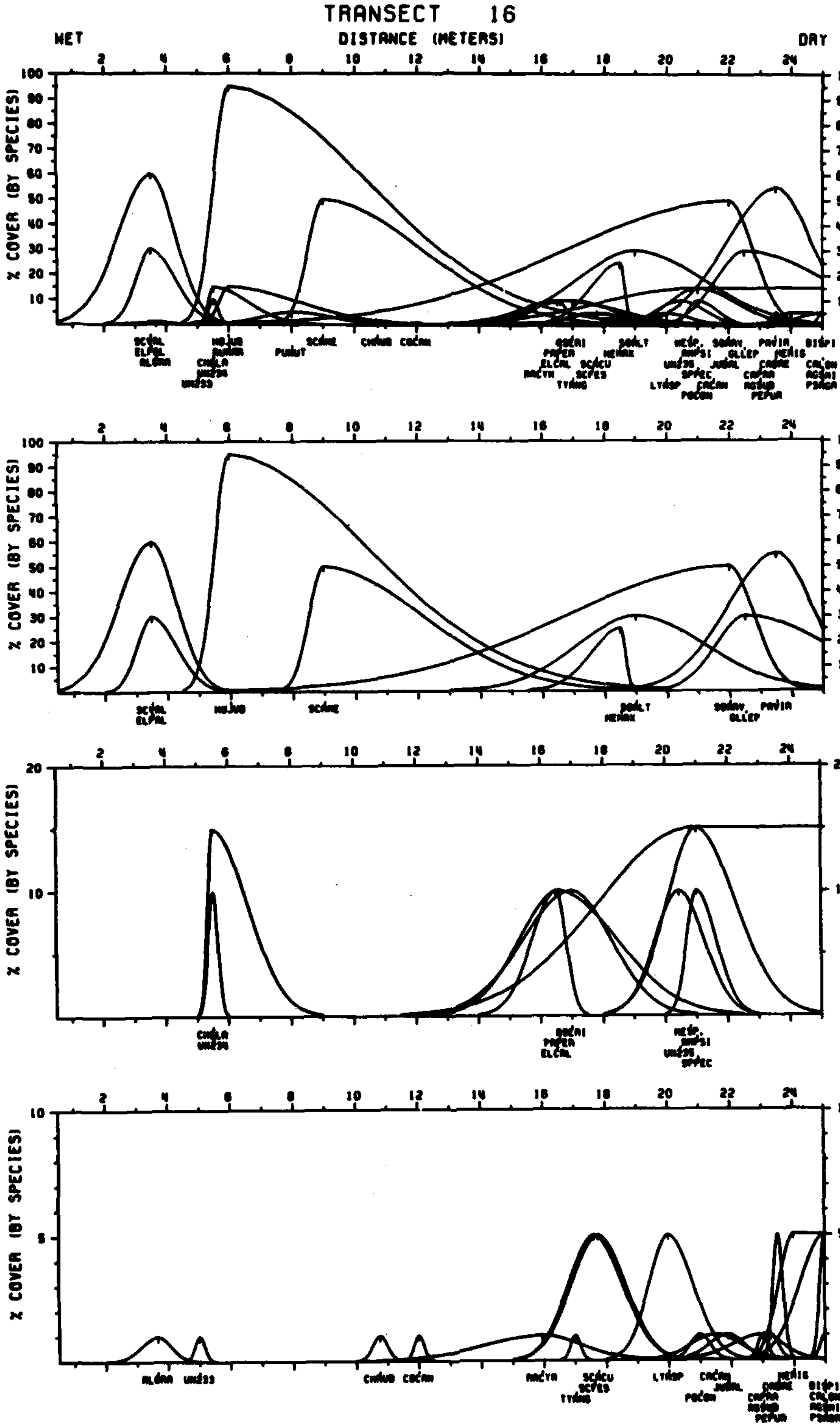


Figure B16. Direct gradient analysis graph, transect 16 (Continued)

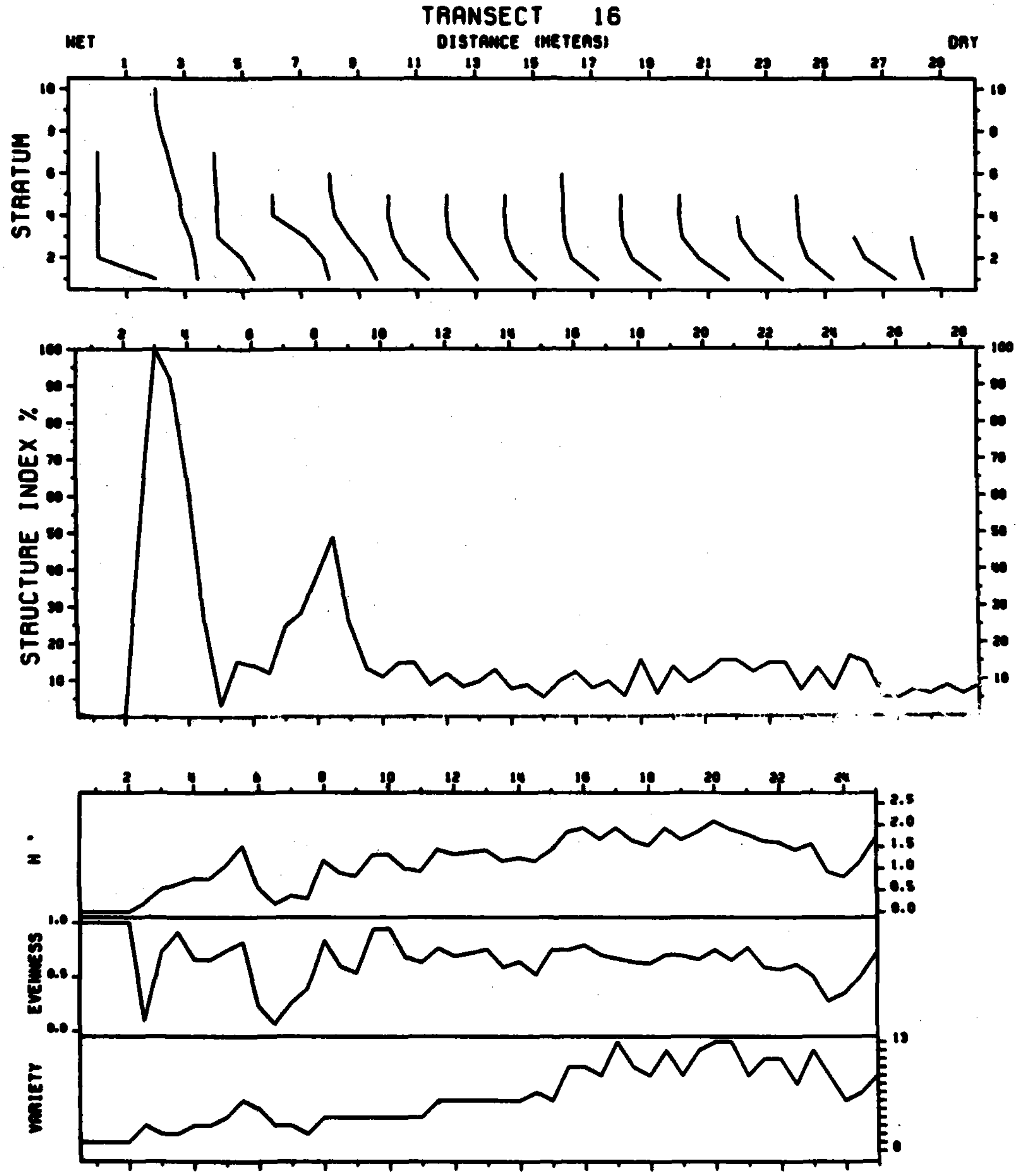


Figure B16. (Concluded)

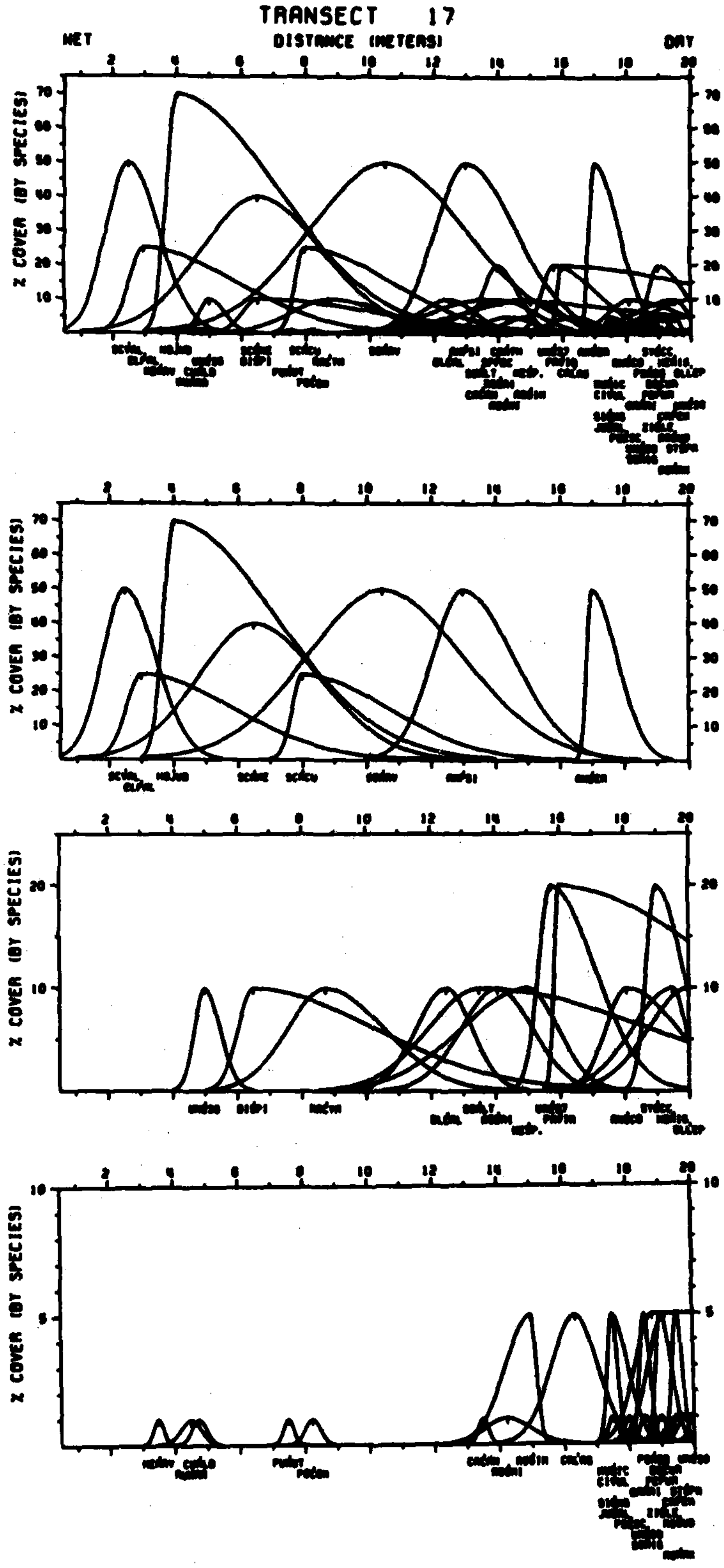


Figure B17. Direct gradient analysis graph, transect 17 (Continued)

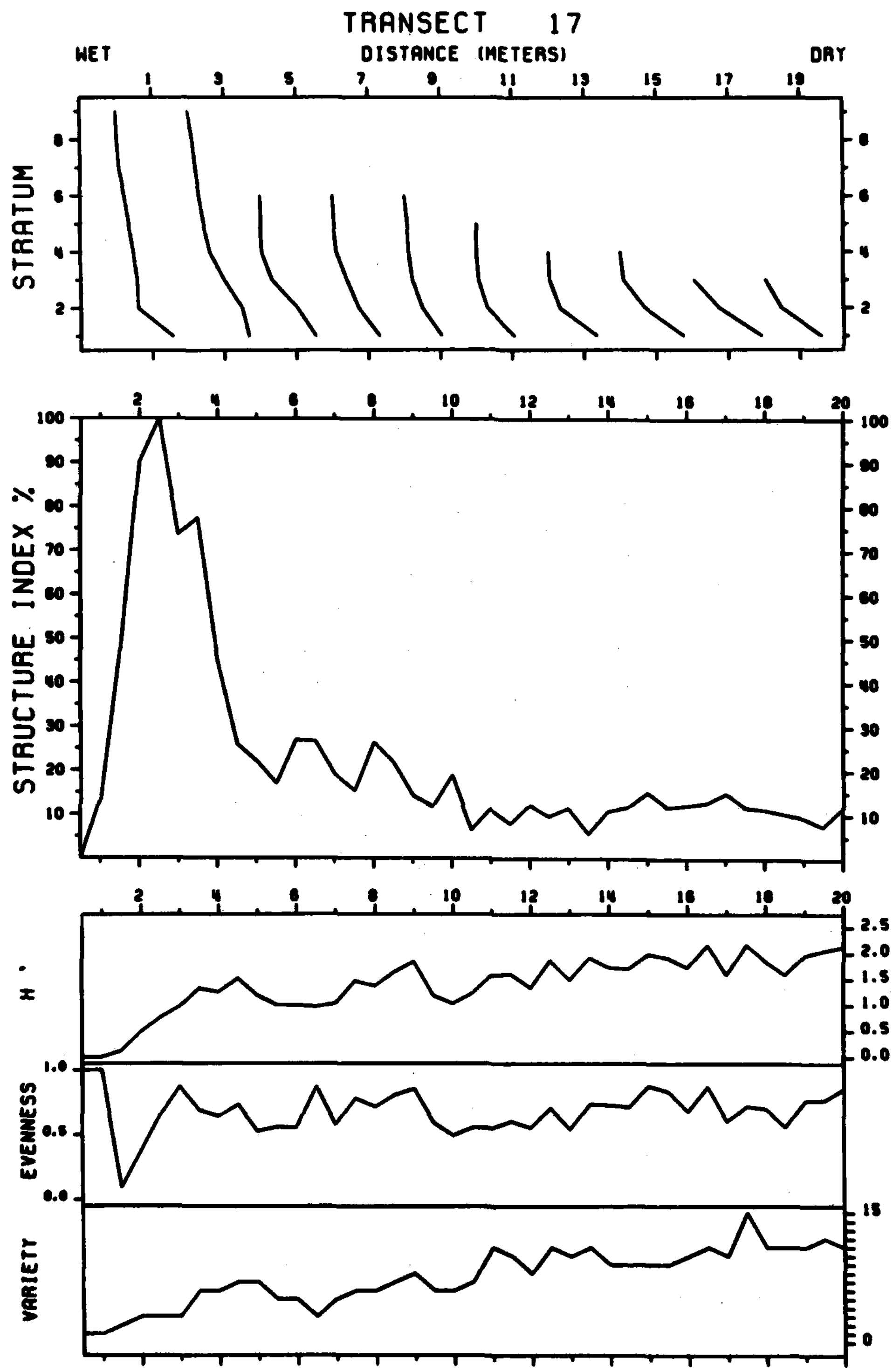


Figure B17. (Concluded)

TRANSECT 18

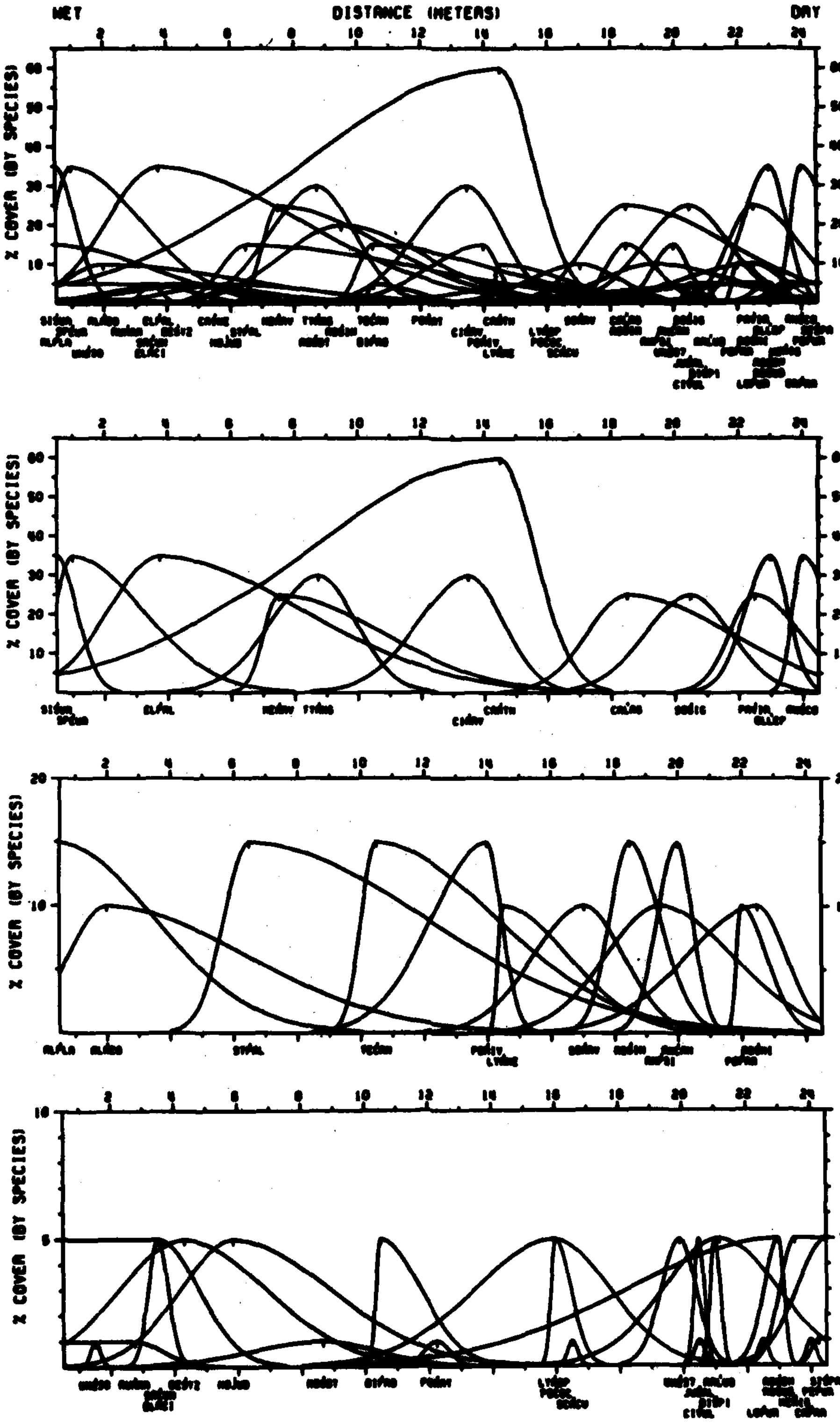


Figure B18. Direct gradient analysis graph, transect 18 (Continued)

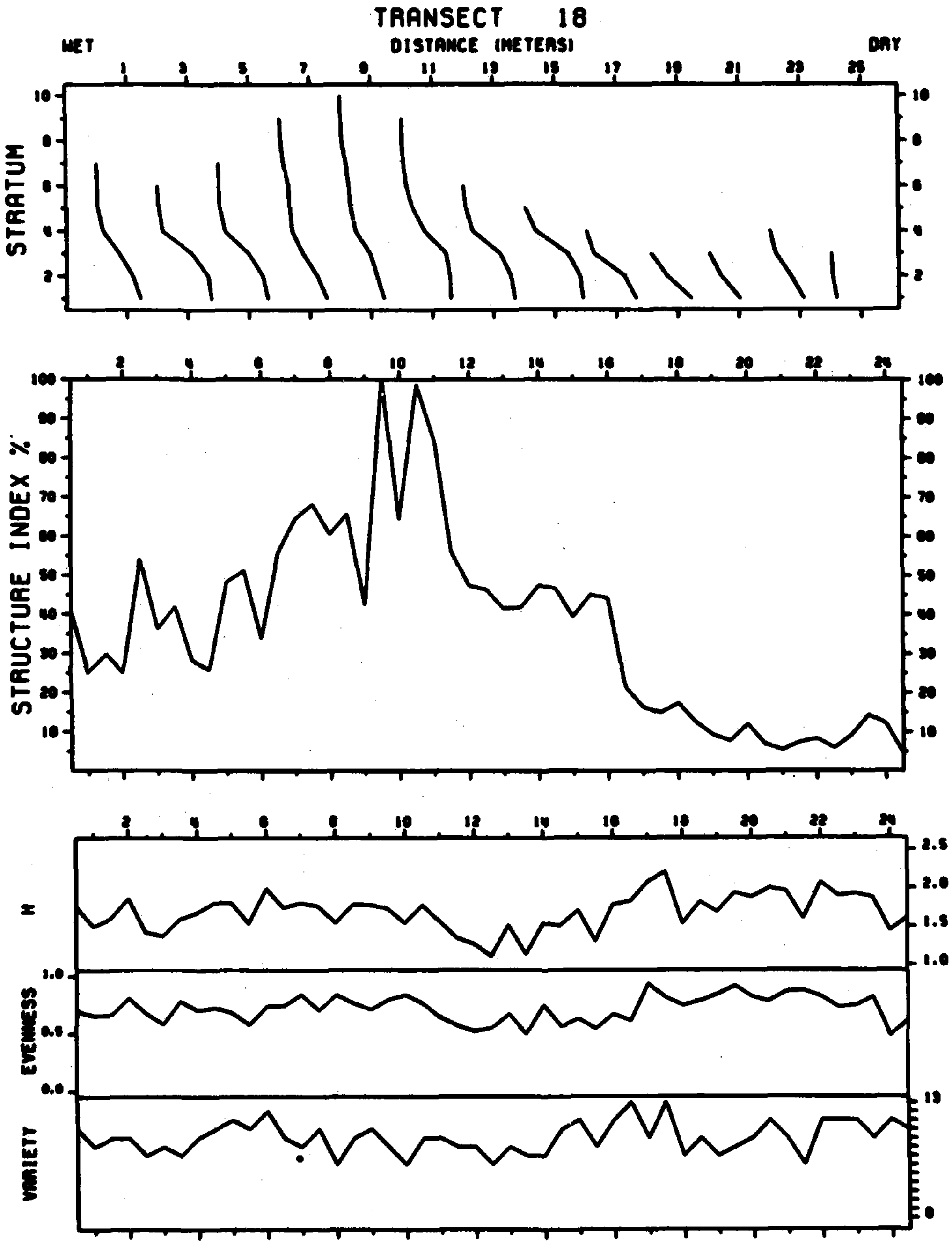


Figure B18. (Concluded)

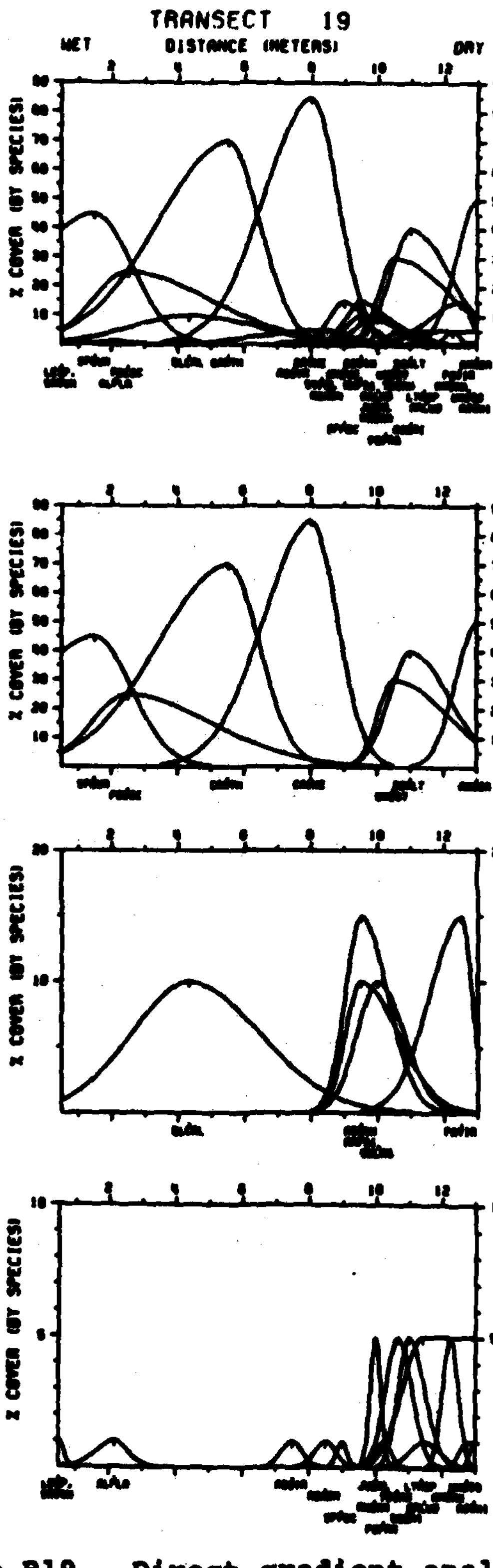


Figure B19. Direct gradient analysis graph, transect 19 (Continued)

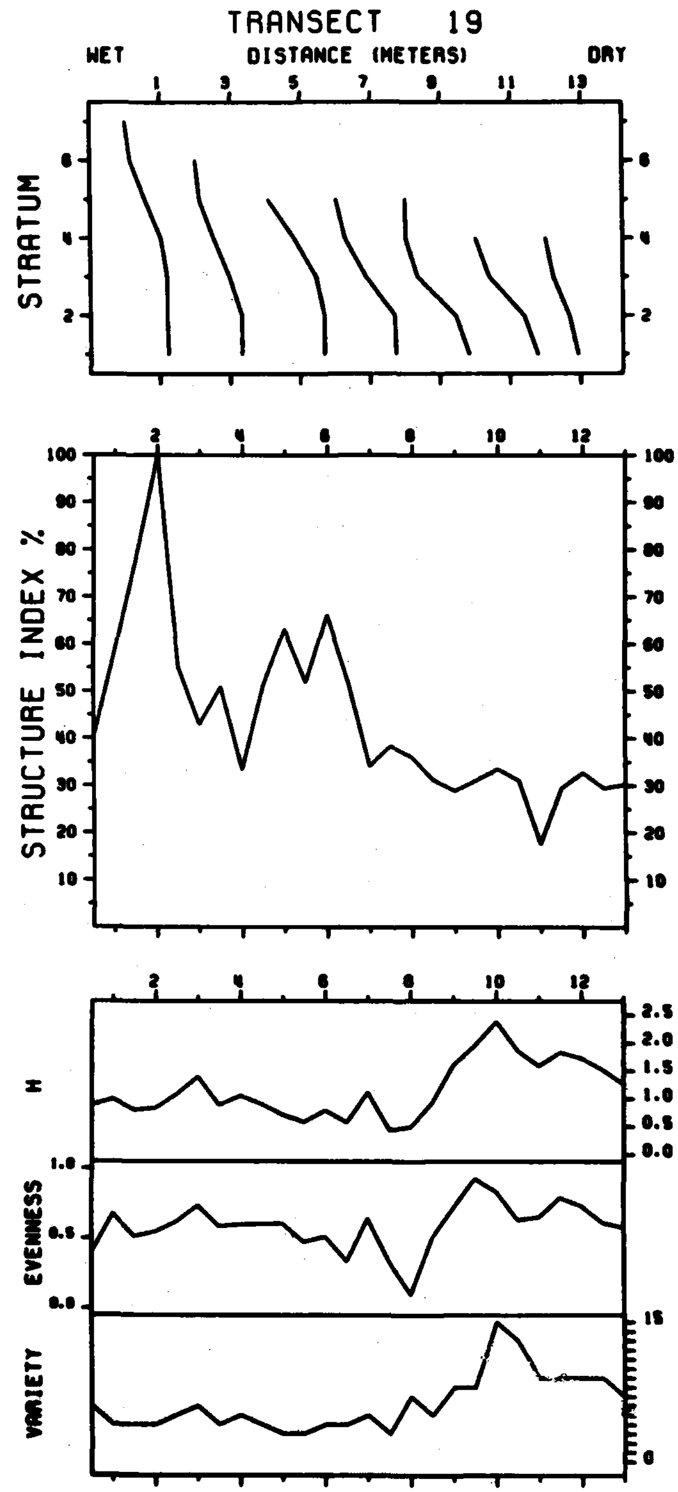


Figure B19. (Concluded)

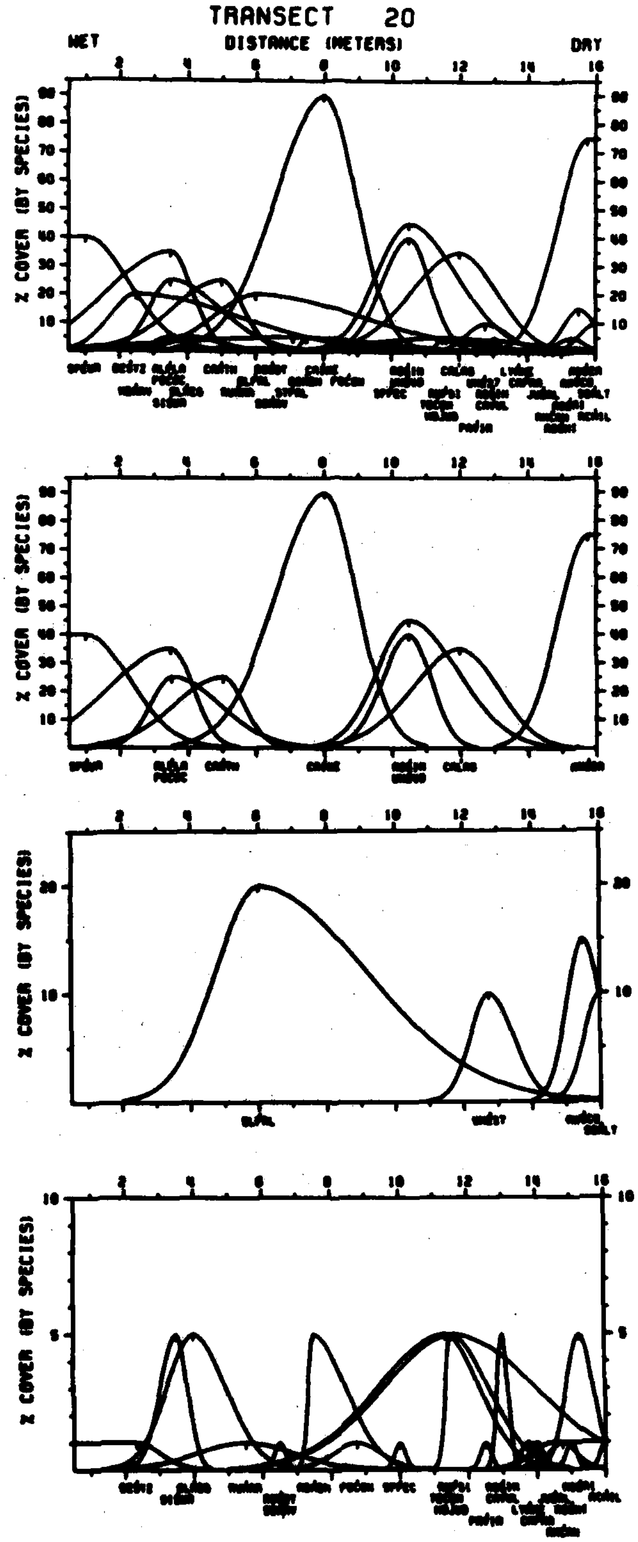


Figure B20. Direct gradient analysis graph, transect 20 (Continued)

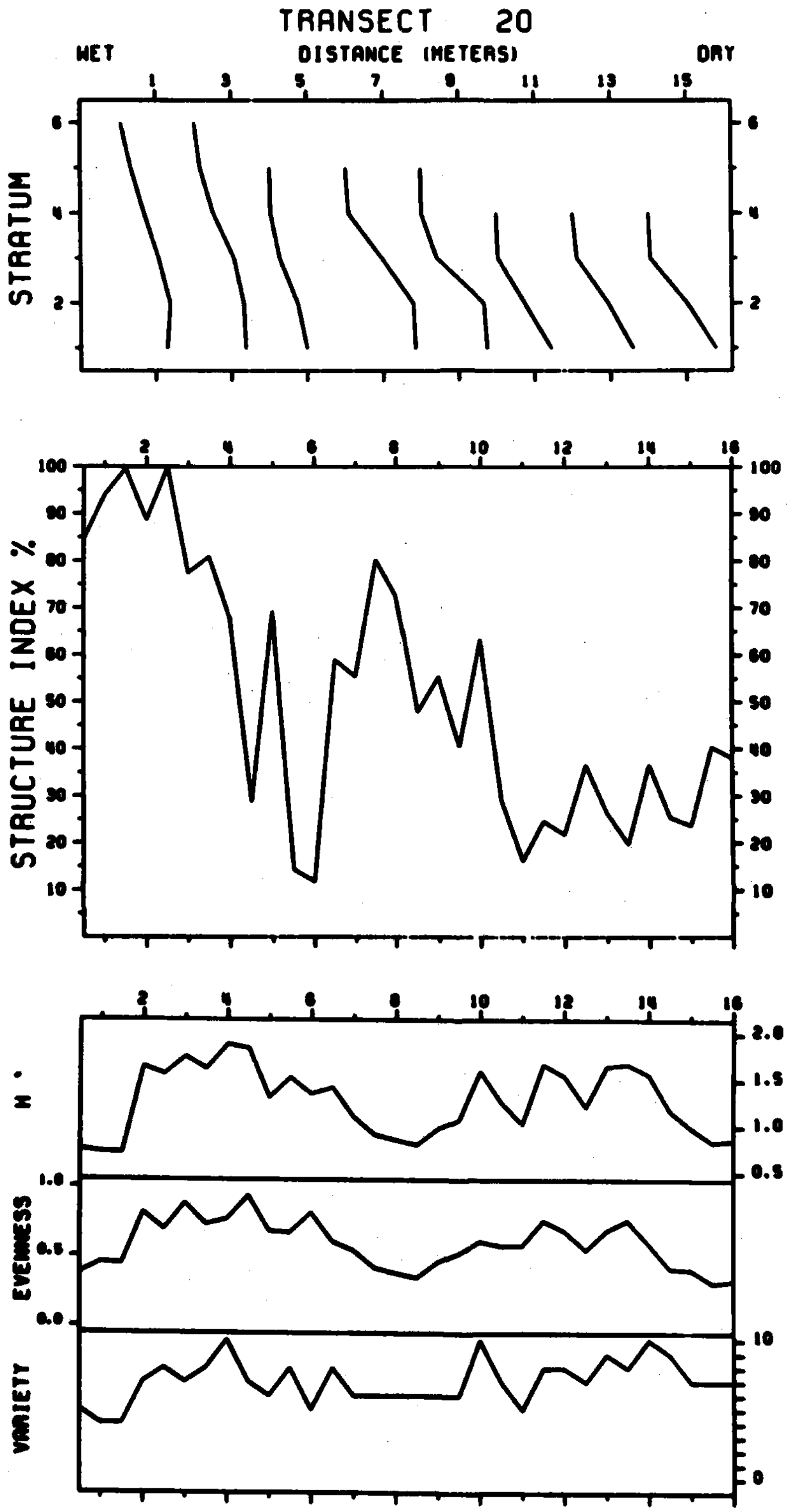


Figure B20. (Concluded)

APPENDIX C: SPECIES SAMPLED

Species sampled in 20 wetland transects, together with mnemonic code and presence value (percent of transects in which a species occurred), are listed below:

Species	Mnemonic Code	Presence %
Acerates viridiflora (Raf.) Eat.	ACVIR	5
Achillea millefolium L.	ACMIL	20
Agropyron repens (L.) Beauv.	AGREP	10
Agropyron smithii Rydb.	AGSMI	90
Agropyron subsecundum (Link.) Hitchc.	AGSUB	15
Agrostis hyemalis (Walt.) BSP.	AGHYE	15
Agrostis stolonifera L.	AGSTO	5
Alisma gramineum Michx.	ALGRA	5
Alisma plantago-aquatica L.	ALPLA	15
Allium canadense L.	ALCAN	5
Alopecurus aequalis Sobol.	ALAEQ	10
Ambrosia psilostachya DC.	AMPSI	80
Ambrosia trifida L.	AMTRI	5
Amorpha canescens Pursh.	AMCAN	20
Amorpha fruticosa L.	AMFRU	10
Andropogon gerardi Vitm.	ANGER	35
Andropogon scoparius Michx.	ANSCO	35
Anemone canadensis L.	ANCAN	35
Apocynum sibiricum Jacq.	APSIB	15
Artemisia frigida Willd.	ARFRI	5
Artemisia ludoviciana Nutt.	ARLUD	20
Asclepias ovalifolia Decne.	ASOVA	5
Asclepias speciosa Torr.	ASSPE	25
Asclepias syriaca L.	ASSYR	30
Asclepias verticillata L.	ASVER	5
Aster ericoides L.	ASERI	35
Aster simplex Willd.	ASSIM	65
Astragalus canadensis L.	ASCAN	5
Beckmannia syzigachne (Steud.) Fern.	BESYZ	10
Bidens frondosa L.	BIFRO	40
Bouteloua curtipendula (Michx.) Torr.	BOCUR	20
Bromus inermis Leyss.	BRINE	15
Bromus japonicus Thunb.	BRJAP	10
Bromus tectorum L.	BRTEC	5
Calamagrostis canadensis (Michx.) Beauv.	CACAN	10
Calamagrostis inexpansa Gray	CAINE	30
Calamovilfa longifolia (Hook.) Scribn.	CALON	10
Carex atherodes Spreng.	CAATH	50
Carex brevior (Dew.) Macken.	CABRE	35
Carex eleocharis Bailey	CAELE	5
Carex laeviconica Dew.	CALAE	25
Carex lasiocarpa Ehrh.	CALAS	45
Carex pennsylvanica Lam.	CAPEN	10
Carex praegracilis W. Boott.	CAPRA	20
Carex vulpinoidea Michx.	CAVUL	15
Chenopodium album L.	CHALB	25
Chenopodium glaucum L.	CHGLA	5
Chenopodium rubrum L.	CHRUB	5

(Continued)

Species	Mnemonic Code	Presence %
Cirsium arvense (L.) Scop.	CIARV	65
Cirsium vulgare (Savi.) Airy-Shaw.	CIVUL	40
Convolvulus arvensis L.	COARV	10
Conyza canadensis (L.) Cronq.	COCAN	10
Cyperus aristatus Boeckl.	CYARI	5
Distichlis spicata (L.) Greene	DISPI	25
Echinacea angustifolia DC.	ECANG	5
Eleocharis acicularis (L.) R. & S.	ELACI	5
Eleocharis calva Torr.	ELCAL	20
Eleocharis palustris (L.) R. & S.	ELPAL	25
Elymus cinereus Scribn. & Merr.	ELCIN	5
Equisetum laevigatum A. Br.	EQLAE	5
Euphorbia esula L.	EUESU	15
Fraxinus pennsylvanica Marsh.	FRPEN	5
Gaillardia aristata Pursh.	GAARI	5
Glycyrrhiza lepidota (Nutt.) Pursh.	GLLEP	20
Grindelia squarrosa (Pursh.) Dunal	GRSQU	5
Hedeoma hispida Pursh.	HEHIS	5
Helianthus annuus L.	HEANN	25
Helianthus maximiliani Schrad.	HEMAX	10
Helianthus rigidus (Cass.) Desf.	HERIG	30
Hordeum jubatum L.	HOJUB	35
Juncus balticus Willd.	JUBAL	25
Juncus interior Wieg.	JUINT	5
Kochia scoparia (L.) Schrad.	KOSCO	5
Lactuca pulchella (Pursh.) DC.	LAPUL	20
Lactuca serriola L.	LASER	25
Lappula echinata Gilib.	LAECH	10
Lemna spp. (*trisulca* L. and *minor* L.)	LESP.	80
Lepidium densiflorum Schrad.	LEDEN	5
Lotus purshianus Clem. & Clem.	LOPUR	5
Lycopus americanus Muhl.	LYAME	50
Lycopus asper Greene	LYASP	55
Medicago lupulina L.	MELUP	10
Melilotus spp. (*alba* (L.) and *officinalis* (L.) Desr.)	MESP.	40
Mentha arvensis L.	MEARV	60
Mirabilis nyctaginea (Michx.) MacM.	MINYC	5
Muhlenbergia cuspidata (Torr.) Rydb.	MUCUS	5
Muhlenbergia richardsonis (Trin.) Rydb.	MURIC	5
Nepeta cataria L.	NECAT	10
Oxalis stricta L.	OXSTR	30
Panicum perlongum Nash	PAPER	5
Panicum virgatum L.	PAVIR	40
Parietaria pennsylvanica Muhl.	PAPEN	5
Petalostemum purpureum (Vent.) Rydb.	PEPUR	20
Phalaris arundinacea L.	PHARU	15
Phleum pratense L.	PHPRA	5
Phragmites communis Trin.	PHCOM	30
Physalis virginiana Mill.	PHVIR	20
Plantago major L.	PLMAJ	5
Poa pratensis L.	POPRA	80
Polygonum coccineum Muhl. ex Willd.	POCOC	65

(Continued)

Species	Mnemonic Code	Presence %
Polygonum convolvulus L.	POCON	45
Polygonum natans (Michx.) Eat.	PONAT	30
Potentilla rivalis Nutt.	PORIV	20
Prunus virginiana L.	PRVIR	5
Psoralea argophylla Pursh.	PSARG	20
Psoralea esculenta Pursh.	PSESC	5
Puccinellia nuttalliana (Schult.) Hitchc.	PUNUT	10
Ranunculus cymbalaria Pursh.	RACYM	10
Ratibida columnifera (Nutt.) Woot. & Standl.	RACOL	10
Rhus radicans L.	RHRAD	5
Riccia (Michx.) L.	RISP.	20
Rorippa obtusa (Nutt.) Britt.	ROOBT	20
Rosa arkansana Porter	ROARK	35
Rumex crispus L.	RUCRI	20
Rumex maritimus L.	RUMAR	20
Sagittaria cuneata Sheldon	SACUN	15
Salix interior Rowlee	SAINT	5
Scirpus acutus Muhl.	SCACU	15
Scirpus americanus Britt.	SCAME	15
Scirpus fluviatilis (Torr.) Gray	SCFLU	35
Scirpus validus Vahl.	SCVAL	35
Scolochloa festucacea (Willd.) Link.	SCFES	50
Scrophularia marilandica L.	SCMAR	5
Sisymbrium altissima L.	SIALT	10
Sisyrinchium angustifolium Miller.	SIANG	5
Sium suave Walt.	SISUA	25
Solanum nigrum L. var. *nigrum*	SONIN	5
Solanum nigrum L. var. *villosum* L.	SONIV	10
Solidago altissima L.	SOALT	40
Solidago gigantea Ait.	SOGIG	15
Solidago rigida L.	SORIG	10
Sonchus arvensis L.	SOARV	70
Sparganium eurycarpum Engelm.	SPEUR	15
Spartina pectinata Link.	SPPEC	85
Sphenopholis obtusata (Michx.) Scribn.	SPOBT	10
Stachys palustris L.	STPAL	40
Stipa comata Trin. & Rupr.	STCOM	5
Stipa spartea Trin.	STSPA	15
Stipa viridula Trin.	STVIR	15
Strophostyles leiosperma (T. & G.) Piper.	STLEI	5
Symphoricarpos occidentalis Hook.	SYOCC	35
Taraxacum officinale Weber	TAOFF	10
Teucrium canadense L.	TECAN	20
Trifolium repens L.	TRREP	5
Typha angustifolia L.	TYANG	65
Urtica dioica L.	URDIO	25
Utricularia vulgaris L.	UTVUL	25
Vallisneria americana Michx.	VAAME	5
Verbena hastata L.	VEHAS	20
Verbena stricta Vent.	VESTR	5
Viola papilionacea Pursh.	VIPAP	20
Zigadenus elegans Pursh.	ZIELE	5
Unknown 201	UN201	5

(Continued)

Species	Mnemonic Code	Presence %
Unknown 202	UN202	5
Unknown 203	UN203	15
Unknown 204	UN204	5
Unknown 205	UN205	30
Unknown 206	UN206	5
Unknown 207	UN207	5
Unknown 208	UN208	5
Unknown 209	UN209	5
Unknown 210	UN210	5
Unknown 211	UN211	5
Unknown 212	UN212	5
Unknown 213	UN213	5
Unknown 214	UN214	5
Unknown 215	UN215	5
Unknown 216	UN216	5
Unknown 217	UN217	5
Unknown 218	UN218	5
Unknown 219	UN219	5
Unknown 220	UN220	5
Unknown 221	UN221	5
Unknown 225	UN225	5
Unknown 226	UN226	10
Unknown 227	UN227	5
Unknown 228	UN228	5
Unknown 229	UN229	5
Unknown 230	UN230	5
Unknown 231	UN231	5
Unknown 232	UN232	5
Unknown 233	UN233	5
Unknown 234	UN234	5
Unknown 235	UN235	5
Unknown 236	UN236	5
Unknown 237	UN237	20
Unknown 238	UN238	5
Unknown 239	UN239	5
Unknown 240	UN240	10

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

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  Use of vegetation in delineating wetland borders in upper Missouri River Basin; North-Central United States / by W. Carter Johnson, Richard A. Mayes, Terry L. Sharik (Departments of Biology, Forestry, and Wildlife, Virginia Polytechnic Institute and State University). -- Vicksburg, Miss. : U.S. Army Engineer Waterways Experiment Station ; Springfield, Va. : available from NTIS, 1982.
  132 p. in various pagings : ill. ; 27 cm. -- (Technical report ; Y-82-1)
  Cover title.
  "August 1982."
  Final report.
  "Prepared for Office, Chief of Engineers, U.S. Army under Contract No. DACW39-78-C-0098."
  "Monitored by Environmental Laboratory, U.S. Army Engineer Waterways Experiment Station."
  At head of title: Wetlands Research Program.
  Bibliography: p. 64-65.

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  Use of vegetation in delineating wetland borders : ... 1982.
(Card 2)

  1. Missouri River Basin. 2. Plants. 3. Sampling. 4. Wetlands. I. Mayes, Richard A. II. Sharik, Terry L. III. United States. Army. Corps of Engineers. Office of the Chief of Engineers. IV. Virginia Polytechnic Institute and State University. V. Wetlands Research Program. VI. U.S. Army Engineer Waterways Experiment Station. Environmental Laboratory. VII. Title VIII. Series: Technical report (U.S. Army Engineer Waterways Experiment Station) ; Y-82-1.
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